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A STUDY OF THE PERFORMANCE OF AN ASTRONAUT DURING INGRESS AND EGRESS MANEUVERS THROUGH AIRLOCKS AND PASSAGEWAYS

ENVIRONMENTAL RESEARCH ASSOCIATES
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PROPRIETARY INFORMATION

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ABSTRACT

A comparative time--displacement analysis, motion picture, was performed to quantitatively assess the feasibility and utility of experiments involving pressure-suited astronaut egress as a result of balanced gravity conditions such as would exist on orbiting non-rotating space stations and vehicles. The experiments were performed using a full scale airlock provided by Langley Research Center, comprising three distinct hatch configurations enclosing a cylindrical passageway. The experiments were performed in the following three modes:

-Ground/normal gravity
-Water immersion/neutral buoyancy
-Aircraft/balanced gravity.

Each of these modes has certain inherent restrictions, e.g. the aircraft is severely space--time limited, water immersion allows external balanced gravity conditions only and the ground experiment is subjected to normal gravity. Comparison analysis of the three modes was accomplished with suit-pressure, subject and suit-type as parameters.

The results of this analysis indicate that the performance of manned egress maneuvers using the water immersion and aircraft modes could be successfully correlated as regards psychological as well as the operational considerations. Due to the mobility decrement afforded by the pressure suit and normal gravity effects the character of egress performance differed between the ground and the two remaining modes. The major dissimilarity evidenced was in the total times of egress as well as discrete task performance times and modes.

Valid experimentation of manned egress under balanced gravity require the performance of water immersion tests backed up with a reduced number of aircraft tests. Ground/normal gravity experiments are additionally required to serve a control and procedure determination function. Due to the scope of Phase I, insufficient testing was accomplished, to qualify this conclusion further. Considerably greater effort will be carried out pertinent to this effect in Phase II.

FOREWORD

Currently planned and scheduled NASA programs include requirements for astronaut extravehicular operations. These operations are performed in conjunction with docking, crew transfer and extra-vehicular maintenance or inspection. To perform these tasks the suited astronauts are required to egress from the pressurized vehicle through an appropriate exit hatch and/or passageway.

The first planned maneuvers of this type occur in conjunction with the Gemini orbital mission. In this egress maneuver, the astronaut simply exits from the depressurized Gemini, executes a short stay inspection and returns. A more sophisticated operation occurs in conjunction with the Apollo lunar landing mission, in that the crew is required to transfer to and from the LEM capsule through an airlock in the command module. These operations will form the basis for the ultimate egress maneuver requirements attendant upon manned space station operation.

Preliminary ground and aircraft demonstrations of egress by WADC, have given rise to serious limitations and reservations. Additionally, it is not possible to operate normally under balanced gravity conditions, particularly in full-pressure suits which as presently conceived sharply impede the performance and movement of the astronaut. Project NAS1-4059 was established to provide an analytical and experimental approach to the general problem of manned egress maneuvers attendant upon space station operation. It is further required to provide design criteria and to establish performance limits and procedures for the astronauts on board 'zero-gravity' space stations.

Discounting actual orbital flight experiments due to considerations of cost and complexity, there exist three basic modes for balanced gravity/airlock experiments; e.g., ground tests in which the maneuvers are performed in real space-time but under normal gravity, water immersion in which the external gravity-associated friction is nullified by fluid buoyancy, but in which the internal organs are under normal gravity and finally experiments in an aircraft executing a 'Keplerian' maneuver. This later test albeit, providing balanced gravity, physiological stimulus is highly restricted due to space and time limitations imposed by the aircraft.

To accomplish the required evaluation, NAS1-4059 Phase I effort proceeded to demonstrate and appraise the optimum mode (s) of experimentation required for the postulation and optimization of the egress/ingress maneuver and airlock operation including ground, water immersion and aircraft tests. Further, Phase I included the demonstration of test in the three modes and preliminary design and planning of more comprehensive Phase II experiments.

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TECHNICAL DISCUSSION

INTRODUCTION

Operational requirements of astronaut(s) performance in a balanced gravity environment, zero-gravity, requires the definition and specification of new equipment and procedures. This design requirement is particularly critical as regards the ingress/egress maneuvers. Ingress/egress maneuvers comprise the movement of pressure-suited and unsuited astronaut(s) through passageways and hatches. Planned programs require the maneuvers to be performed in both an internal and external mode. For the Gemini project the astronaut(s) will exit from the unpressurized vehicle into free space; the Apollo project requires the internal transfer of astronauts to and from the Command Module and the LEM. Subsequent zero-gravity space station operations will probably require both types of ingress/egress and will additionally include materials transfer, emergency operation with multi-manned access and will require repetitive cycling.

Two main phenomenological factors contribute to the difficulty of design and design specification in this area as regards airlock, hatch and passageway design as well as the ingress/egress procedures. These factors are the absence of external friction due to weightlessness and the performance decrement occuring as a result of manned operation in a full pressure suit in a balanced gravity environment.

NAS1-4059, A Study of Astronaut Performance During Ingress and Egress Maneuvers Through Spacecraft Airlocks and Passageways, was initiated to supply design and performance information pertinent to this critical area. The project comprised the measurement of the performance of suited astronauts in full-scale airlocks and hatches under simulated balanced gravity conditions. Phase I effort was restricted to the proof of feasibility of experimental techniques and analytical procedures.

METHOD

Ingress/Egress Maneuver

The ingress/egress maneuver is one of the most critical operations to be performed in space on board a zero-gravity space station. It is during this maneuver that the sealed integrity of the station is momentarily broken, i.e. the hermetic sealed hatches of the airlock are required to function. This maneuver is further complicated by the repetitive operating requirements evidenced as a result of docking, crew supply and rotation, and extravehicular maintenance and inspection functions imposed by space station type missions. While these requirements do not, ab nova, exercize a once-a-day constraint, most pre-orbital design planning impose this level of cycling. During the ingress/egress maneuver the astronaut(s) are required to transfer between two pressurized compartments, e.g. as in the Apollo mission or to transfer between the pressurized station compartment and free space or other unpressurized vehicles or compartments.

The more sophisticated ingress/egress maneuvers evidenced as a result of planned space station operation require the interposition of an airlock component to prevent undue or excessive loss of breathing gases. A normal airlock configuration comprises two hatch elements connected by an intervening, air tight, passageway. The astronaut is required to make a transition from the normal pressurized station environment, probably shirt sleeve, to a self contained existence in free space or other, via an anthropomorphic full pressure suit and life support unit. This combination unit, an outgrowth of the current Navy Mark IV-FPS, affords a non-rigid sealed-gas containment at a pressure equal to or slightly less than that normally existing on the station. The utilization of this type protective suit in its latest space versions, considerably impedes the mobility, vision and comfort of the astronaut in its pressurized condition. Current estimates of the expected operating pressure, range between 3.4 and 5 psia with some advanced NASA interest tending toward even higher, less mobile quasi-rigid suits for use at 10 psia.

The chosen operating pressure is a compromise between considerations of human comfort, safety due to hypoxia and increased weight penalties due to containment considerations. In order to demonstrate the feasibility of the thru experiment modes in Phase I, a representative ingress/egress task performance analysis for normal mode operation was performed and appears in Table I. The basic ingress/egress maneuver was performed in an analogic manner in each of the three experiment modes, e.g. ground/normal gravity, water immersion/neutral buoyancy and aircraft/balanced gravity. A comparison time--displacement analysis was made from motion picture coverage of the three modes, in which total operation times and individual tasks times were measured. Experiments were run in the ground/normal gravity mode wherein time-displacement was measured with suit type, pressure, subject and maneuver direction as the parameters. Due to the intended scope of Phase I, a reduced set of experiments in the remaining two modes was performed. These remaining experiments were performed at a pre-selected fixed pressure level by a single subject.

APPARATUS

Airlock

For the feasibility demonstration phase, it was decided to use the existing LRC--Mod. II mockup airlock which was supplied to ERA. The airlock mockup, Figure 1, comprises a nominal 48 inch diameter, 72 inch long, cylindrical passageway closed by two 48 inch diameter circular ends which serve as the hatch frames. Three hatches allow entry into the passageway, one at either end, a 36 inch circular and a 28 inch by 42 inch oblong, and a 32 inch circular hatch entering from the side, unsymmetrically displaced. The hatches are representative of those currently employed in the airlock seal tests at LRC and are of the side-hinges, conventional O-ring type. The hatches, Figure 2, are of the manual type with the seal engagement afforded by a central rotary actuated multiple-cam arrangement. The anticipated maximum force requirement for actuation is 40 foot-pounds torque, which is provided directly by the astronaut or test subject through a 24 inch diameter double bar handle, the handles being approximately 1 inch diameter. The multiple latch bar configuration was modified slightly to accommodate fabrication and is shown in Figure 3. Two separate structural bases were provided to support the airlock during the experiments, a fixed structure supplied by LRC and a mobile structure fabricated by ERA personnel. Modification to the handles and hinges was accomplished to compensate for original equipment degradation as a result of water immersion tests. Access ports were provided in the airlock ends to permit funtioning of the communications elements during the experiments.

Additional supports were provided by LRC to permit safe stowage of the airlock in the C-131B aircraft for the experiments in the aircraft/balanced gravity mode.

Pressure Suits

The current Navy, Mark IV, FPS MOD 0 was chosen in order to approximate the experimental extravehicular full pressure suit configurations for the following reasons:

- The mobility decrement afforded by the Mark IV, FPS is reported to closely approximate the mobility decrements afforded by such advanced suits as Gemini, Apollo and the planned ORL suits (1).

- The Mercury suits as used in the orbital flight phase were modified Mark IV, FPS suits.

- The Mark IV suits are currently used as design targets by suit manufacturers.

- The cost and availability of the Mark IV, FPS is commensurate with the program budget and time schedules.

(1) Lockheed Aircraft Study Program for NASA--MSC relative to LORL Concept

The Mark IV full pressure suit, consists of a two-layer garment comprising a hermetic inner rubber layer and an outer nylon restraint garment. Entrance to the suit body is afforded through the shoulder to thigh circumferential double-sealed zipper. Appropriate tab inserts and lacings are provided for lengthening or shortening the arms, legs, torso length and circumference, and the neck circumference. The suit terminates at the neck in an open seal-bearing-locking ring which mates with the helmet component. The neck ring further serves as a pivot for the helmet. High capacity, adjustable restraints are further provided for restraining the neck ring in a tension mode to restraining the shoulder elements. Two quick disconnect ports are provided on the subject left side for vent air and 'G' suit attachments. An additional port is provided on the right side which acts as an exhaust port and sensing line. The rubber feet of the suit are integral with the suit and are incapsulated by thermos bottle type boots which serve an insulating and restraint function. An internal tubular vent system is supplied with the suit which acts to cool the suited subject. A breathing regulator, communications unit, head restraint, visor and breathing gas pressure control elements is incorporated into the high strength plastic helmet component. The helmet is sealed to the suit via a bayonet-lock-bearing neck ring. Compressed air, oxygen, or mixed breathing gases enter through the helmet regulator port on the head side of the integral face seal upon subject demand. Lowering the pressure on the helmet side of the regulator due to subject demand by approximately 0.07 psi causes pressure assisted injection of breathing gas to the portion surrounding the subject facial area from the 50-90 psi side of the second stage regulator. Exhalation of gas by the subject causes a resultant pressure increase in the inner face seal area, closing the check valve on the helmet regulator and causing gas to be expelled into the suit area through the one way valve located in the face seal. This further acts to pressurize the suit to the level dictated by the controller and/or relief valve depending on the set pressure level. The relief valve is a fixed level, 3.4 psig, spring-loaded unit located on the lower left leg portion of the suit.

Two similar versions of the Mark IV suit, Figure 4, 5, were provided: The Arrowhead and the Goodrich versions. Considerable difference in mobility and motion mode was encountered between these suits.

Suit Modifications

The suits as provided by the Navy were designed to operate in conjunction with current USN high performance aircraft. They are designed for maximum ease of operation in a seated position and operate mainly in an unpressurized conditions until the event of emergency such as loss of cockpit pressurization. The suits are designed for normal operation with a two gas system, i.e. vent air supplied from the jet-engine intake compressors or the aircraft bailout oxygen system. Suit pressurization is maintained by allowing or restricting vent air exhaust by means of the suit controller. Unpressurized operation entails a slight suit pressurization thru the vent air system.

Figure 6 depicts schematically the modified breathing gas pressurization system provided by ERA in conjunction with LRC. Figure 7, shows the test subject wearing the final self-contained breathing and pressurization system. In this system the only component retained from the Mark IV pressurization unit is the second stage helmet regulator. High pressure breathing gas storage, compressed air, is provided by the modified SCUBA tank and backpack element which comprises a 2500 psig storage combined with a first stage 50-90 psig regulator and low-level tank capacity alarm unit. The 50-90 psig supply is fed into the helmet regulator by a short quick disconnect line. After visor release, the visor seal is pressurized causing face-plate sealing and locking. Breathing gas is admitted to the helmet area upon subject demand as previously described. No cooling air is provided for the suits in this mode and, therefore, the two auxiliary ports are closed with blind-flange disconnects. Pressurization takes place in response to demand and is controlled by the relief valve unit provided by LRC. This relief valve is a spring loaded component which is preset from 0-3.4 psig prior to each experiment by calibration with the auxiliary gauge unit shown in Figure 8. This type pressurization unit more closely approximates the contemplated backpack or chest pack life-support units currently considered by NASA. A modified 'telephone type' communications unit, Figure 9, was provided to accommodate safe performance in the water immersion experiments and to further permit simultaneous recording of subject instructions and comments during the experiments. This unit was a hardwire type necessitating airlock modifications as previously described.

During the course of the experiments, it was observed that the performance of the subject in all modes was greatly discommoded by the flight type boots originally supplied with the suits. This was adjudged to be caused by two factors:

- The shoes were extremely rigid, preventing adequate tactile sensation and pedal rotation.

- The soles and heels as provided did not provide adequate frictional characteristics for the required motion.

Conventional flexible athletic foot-wear, Figure 10, was substituted in later tests and proved highly successful both from a subjective viewpoint and in that maneuvers were permitted at maximum pressures which were previously unsuccessful when flight-type footgear were used.

Photographic Equipment

The bulk of the comparison analysis was performed by time displacement-motion analysis utilizing motion picture records of the individual tests comprising the experiments. All motion picture coverage was performed with 16 mm. camera equipment, either by LRC, ERA or USAF personnel. During the course of the experiments, an optimum camera configuration was developed capable of successful performance in all experimental modes. The camera employed was a Bolex-Pailliard 16 mm. model, Figure 11, equipped with battery operated motor drive. This camera was provided with two lenses, a normal view angle 25 mm. Wollensak f/1.9 Cine, Raptar, and a 3'' f/2.8 Wollensak Cine Telephoto lens, and was further provided with a waterproof sealed plastic case and tripod assembly for use in the water immersion test mode. Initial photographic coverage for the underwater tests was provided by a water-tight surface box from LRC, but this arrangement was discontinued due to the inadequacy of coverage afforded by the necessary viewing angle.

Time-motion analysis was performed by visual observation with a Craig-Kalart 16 mm. film editor modified by the inclusion of a frame counter, Figure 12. The 16 mm. films were taken at 24 and/or 16 fps depending on the camera employed. Subsequent films in the second phase will be taken at the 16 fps setting to accommodate the underwater Bolex unit performance and to provide continuity.

Camera coverage in the 'Zero-Gravity' aircraft by the USAF proved inadequate due to lighting requirements and faulty equipment. Subsequent camera coverage in the aircraft will be provided by ERA personnel using TRI-X reversal film and the Bolex-Pailliard camera.

AUXILIARY EQUIPMENT FOR THE VARIOUS MODES

Ground/Normal Gravity

Initial tests on the ground/normal gravity mode evidenced an extreme hardship in the entry and exit tasks, particularly at the higher pressures as a result of the height of the door-step. The initial tests provided no step-up, the door-sill dimension was approximately 12 inches from the floor level. An elevated platform, Figure 13, level with the airlock interior was provided by ERA in later experiments to eliminate this hardship from the ground/normal gravity experiments since this problem had no balanced gravity analogy.

Aircraft Zero-Gravity/Balanced Gravity

The modifications for the aircraft/balanced gravity mode comprised two structural changes to the fixed support base of the airlock and were performed by LRC personnel in response to requests from WADC--USAF. These changes comprised the inclusion of a 1/8 inch plywood sheet to facilitate tie down in the aircraft. Additional modifications were made by WADC aircraft maintenance personnel prior to the aircraft tests and comprised the addition of steel angle tie down straps on the carriage bottom cover plate.

Water Immersion/Neutral Buoyancy

The major equipment modification required by the water immersion experiment mode related to the full pressure suit worn by the subject. The airlock modifications comprised two straight-forward elements; the fixed structural support element was replaced by a wheeled carriage to facilitate placement in the pool. The wheels were of the locking castering type. Lead weights were additionally required to stabilize the airlock underwater and were placed on the ledges provided on the carriage.

Additional modification to the full pressure suit was required to provide the neutral buoyancy conditions necessary for the external balanced gravity condition. The subject was provided with an appropriate number of lead weight elements, both interior and exterior to the suit placed so as to provide neutral buoyancy and stability, Figure 14.

EXPERIMENT DESIGN

General Considerations and Test Subject Requirements

The general structure of the feasibility tests comprised the parametric comparison of the time-displacement performance of pressure suited ingress/egress via the three experimental modes. Using total and/or task time as the dependent variable and pressure as the independent variable, performance was compared with experiment mode and maneuver direction as the parameters. Later experiments were performed with suit type and subject as the parameter. Motion--study and subjective performance analyses were performed to determine whether the tests could be successfully accomplished in the three modes and further ascertain the feasibility of intercorrelation and extrapolation to actual orbital conditions.

The experiments comprised the performance, in an ordered fashion, of the ingress/egress tasks depicted in Table II. It is obvious that the tasks presented in Table II form a simplified, reduced set of tasks depicted previously in Table I. Experiments were performed using deflated-pressure suited performance as control. Runs comprising unsuited performance were also included in the ground/normal gravity mode to allow visual comparison of the suit mobility decrement. Subsequent experiments were performed with subject, maneuver direction suit-type and suit pressure as variables. Replicated data runs were accomplished for the ground mode only, since the scope and funding of Phase I was restricted to feasibility demonstration. A simplified, reduced experiment set was performed for the aircraft and water immersion mode.

Experiment performance in the several modes is analogically similar except that the aircraft mode requires breaking the maneuver down into 10 second intervals to accommodate the maximum 'Zero-gravity' performance of the C-131B Aircraft. Table III lists the average 'Zero-gravity' of current operational aircraft. Involvement of the more sophisticated KC-135 was not considered necessary since the additional small time increment did not appear to offer sufficient advantage. Scheduling of the USAF, C-131B at WADC is considerably simpler than for the KC-135.

Two subjects were used in Phase I experiments, Messers G. Samuel Mattingly and William Franz of ERA. Complete runs were accomplished by Mr. Mattingly while Mr. Franz was used as a back-up for ground experiments due to his time of entry in the program. Mr. Franz has subsequently been checked and balanced out for Phase II experiments in the water immersion mode. The subjects anthropometric data is given in Figures 15-16.

Subject Physical and Indoctrination Requirements

All subjects selected for experiment participation are required to have as a minimum, the following physical and indoctrinational validation:

- A current flight physical (FAA Class III or higher
- Successful completion of the Full Pressure Suit Indoctrination Course at NAS, Norfolk Virginia or equivalent.
- Military High-Performance Aircraft Survival Training
- High Altitude Indoctrination including Explosive Decompression.
- Ingress/Egress Experiment Indoctrination

Additonally, all subjects are required to have a current normal electro-cardiograph tracing and to be above average swimmers. A sample of the requirement validation certificates is given in Figure 15 for Mr. Mattingly.

EXPERIMENT PERFORMANCE AND RESULTS

Figure 17, summarizes the results of the Phase I experiments and entails forty-three runs performed in the three experimental modes. The majority of tests were performed using the ground/normal mode due to scope and costs of the alternate modes and in order to substantiate the ground/normal mode as the control. Mobility decrements for the suits, direction pressures and subjects were ascertained and are shown in Figures 18-21. Comparisons of the water immersion and aircraft mode were performed and are presented in Figures 22-23. The three modes are depicted photographically in Figures 30-32 and are shown in detail in the film supplement.

Ground/Normal Gravity

The modified airlock ingress/egress task analysis, Table II, was used in the ground/normal gravity experiments in order to develop the ground rules for the total experiments and to acquire replicated subject-parameter data. The subject was required to perform the specified tasks in real-time both unsuited and suited with pressures of 0, 1, 2, and 3 psig. The pressures were maintained by setting the relief valve, Figure 6, at the proper level, then depressurizing and replacing the pressure calibration unit with a blind flange assembly to prevent equipment interference during the maneuver.

Prior to experiment startup a briefing was conducted to assure continuity of performance. The communication lines were first laid out thru the airlock so that the subject was always carrying the lines clear of the airlock while moving in a forward direction. Continuous camera coverage was maintained in a plane normal to the direction of travel and the subject task performance times were taken with a stop-watch and then check by film analysis.

Two subjects were used in the ground tests, Figure 15, 16 and evidenced different performance characteristics with regards to suit and mode of performance. In the initial series of runs at ERA, subject 1 was required to perform normal ingress/egress but no platform was provided to aid in the entry phase. Previous preliminary run-throughs at NASA-LRC had employed an initial step-up level with the airlock interior floor. In this series of runs, successful egress was prohibited at the 2 and 3 psig levels due to mobility decrement of the suit. The subject could not exercise the proper balance control and further could not bend his legs sufficiently to clear the exit. Subsequent runs were performed with additional external platforms, level with the airlock interior floors. All further runs including both subjects were successful.

A further modification was made to the experiment format during this first series, in that, the standard military flying boots, were replaced by flexible athletic shoes, Figure 10. This modification was required to provide the test subject with proper pedal--friction--output and mobility. Subsequent subject performance with this modification yielded a noticeable decrease in performance times, increased mobility and significantly decreased the effort required for task performance.

In all, there were thirty-six complete ingress/egress maneuvers performed with the ground/normal experiment mode by ERA personnel. The experiment results are tabulated in Figure 17 and are shown in Figures 18 thru 23. The total maneuver required the unaided ingress and egress of the subject in a task format, Table II which comprised a simplified version of an actual task performance format, Table I. The greatest performance difficulty was noted in the turnaround position of the maneuver. These were required in order to close and latch the hatch (1) and to open and latch hatch (2). This difficulty resulted in the large task performance times noted in Figures 18, and 19. Closing and latching of the hatches was performed with relative ease in the ground mode. This did not prove the case in the water immersion and aircraft experiment modes, as will be discussed later. This relative ease of operation was caused by the subjects ability to provide and apply torque and thrust to the handles by virtue of the effect of gravity and attendant external friction. When this normal gravity associated weight is absent, considerably greater difficulty is experienced both due to force output decrement and due to subject decision--feedback effects required to ascertain the proper force application mode and positions.

The subjects were usually required to perform a substantial number of complete runs during any one experiment set. No external cooling was provided for the suit at any time. The subjects noted greater fatigue and discomfort while performing the ground/normal mode experiments. This effect was anticipated since the work--effort expenditures are greater in this mode than in the other modes.

In general, performance in the ground/normal mode proved to be analogus to performance in the other modes except in the hatch closure and latching task. Modifications to the equipment for the ground/normal mode are planned to compensate this effect.

<u>Aircraft/Balanced Gravity</u>

The modified task format was similarly performed in the C-131B aircraft during balanced gravity flight. This balanced gravity flight was attained by flying a 'Keplerian' trajectory wherein the aircraft performed the following flight plan. The maneuver Figure 28, began at an altitude between 10 and 17 thousand feet, and was initiated by a 10 degree dive during which climb power on both engines was maintained. As the aircraft speed was approached 240 KIAS the dive was terminated by a two to two-and one half gravities pullout at a pitch angle of 42 degress (+). After the nose of the aircraft passes the horizon the co-pilot maintains zero longitudinal acceleration by adjusting power. During this phase the pilot controls the attitude so that the Zero-gravity level is maintained in the experiment section until a 30° (-) pitch attitude is reached. At this time, a smoothly powered pullout is performed. A warning is given by the pilot, prior to all parabolas and a second warning is given 10 seconds prior to entry to the two and one half gravities phase. A five second warning is further transmitted prior to parabola cessation. The total useful time at 'Zero-gravity' in the C-131B is approximately 8-10 seconds, necessitating careful planning of the experiment by tasks so that adequate information is obtained while maintaining proper safety procedures. The modified task performance schedule and time estimates for the aircraft/balanced gravity mode is shown in Table IV.

The Phase 1, aircraft experiments were performed by a single subject during fourteen (14) parabolas accomplished in two separate flights. Camera coverage in this phase was supplied by USAF/ASD personnel and comprised a view from a fixed motion picture camera at approximately 45° to the normal direction of travel and an alternate view from a hand-held camera along the direction of travel. Subsequent camera coverage, in Phase II, will be obtained by ERA personnel and will comprise simultaneous, normal and parallel coverage, with one fixed and one manually operated camera.

Observation and analysis of the ingress/egress task performance in the 'Zero-gravity' aircraft showed that the performance aspects of the task are analogus to ground and water immersion tests. Two attendant characteristics, however, complicate the analysis and correlation. Both of these characteristics are due to performance limitations imposed by conventional aircraft employed in this manner. The primary deviance is a result of the limited 'Zero-gravity' time available relative to the actual total mission performance time, on the order of 5-10%. This time decrement is evidenced not only in the C-131B but also in the KC-135 which exhibits approximately a 50-100% time increment increase over the C-131B. A second, and probably more serious problem is caused by the flight profile requirement of superposition of an initial two and one half gravity maneuver acceleration necessary to attain correct flight speed. This causes considerable mental and physical stress on the subject during each test run. Further, Soviet experiments on the postual response of rats and mice due to two and one half to '0-g' step excitation concluded that true 'Zero-gravity' performance is not attained for at a minimum of 40 sec. after the excitation (2). These effects tended to make the subject perform the ingress/egress task at a faster rate than in the other modes, and indeed, the subject commented that the speed of performance of the individual subtasks was related to the time required to prepare for the onset of the two and one half gravity pullout phase.

The most significant results obtained from the aircraft tests were in the area of the hatch operation, turnaround and final egress. The

(2) Postural Response Effects of a 'Zero-Gravity Transition-NASA Technical Translation

overall performance of the subtasks appeared to be physically less strenuous albiet the two and one half gravity to 'Zero-gravity' pullouts proved extremely tiring to the subject. Some consideration to modifying the flight profile to a one gravity to 'Zero-gravity' pullout phase will be given and possibly tested during Phase II.

Water Immersion/Neutral Buoyancy

The greatest experimental latitude was provided by the water immersion mode. In this mode the subject was required to perform the ingress/egress maneuver in the standard manner while fully immersed in water. The tests comprised performance of the maneuver through the airlock which was also immersed to a depth of eleven feet in the ERA pool facility located on McDonogh Road in Randallstown, Maryland. The pool was provided with an adequate filtering system to maintain visual clarity.

Balanced external gravity was obtained by proper weighting of the suited/pressurized subject, such that a zero-net buoyant force was attained. By proper weight placement, Figure 14, relative to the subjects body and body segment mass centers, balanced gravity stabilization in roll, pitch and yaw as well as balance with respect to the total body could be maintained. The total quantity of weights added as well as their distribution had to be adjusted for each pressure setting. Controlled environment was maintained by the modified SCUBA equipment provided, Figure 7.

The test procedure comprised an initial checkout and weight placement phase followed by a task performance phase. Adjustments to the weight placement was further required for change in subject and/or suit. Considerable difficulty was evidenced in Phase 1 due to equipment failure as a result of airlock and pressure suit degradation resulting from continuous water immersion.

Observation, analysis and subject comment relevant to water immersion mode; admitted a strong correlation between this mode and the aircraft mode, particularly as regards the tasks requiring the application of force such as latching and motion. Performance of the ingress/egress task in the water immersion mode appears to more closely approximate the actual real-time situation than any other mode.

The most serious drawback of the water immersion mode deals with drag associated phenomena. This deleterious effect is highly mitigated as a result of the actual motion velocities experienced and due to the spatial constraints of the airlock. This effect is being analyzed in more detail in Phase II.

Observations, yield a close correlation between the aircraft and water immersion modes of the counter-rotations evidenced as a result of torque application in the latching task and to the 'soaring' phenomena evidenced during the egress task.

DISCUSSION OF EXPERIMENT RESULTS AND CONCLUSIONS

Ingress/egress through airlocks and passageways as currently conceived for 'Zero-gravity space station missions involve relatively low speed, short--duration space--limited restricted space free-floating maneuvers by suited--pressurized astronauts. The tasks involved, are those comprised of transfer through hatches and passageways, communication, inspection and the operation of various airlock equipment such as hatches and locking devices, depressurizing hardware as well as lighting, communication and various environmental sensors. Further, later, more sophisticated missions will require the airlock and passageway to serve as staging areas for manned extravehicular exploration and for crew and resupply and materiel transfer. The NAS1-4059 Phase I feasibility demonstration has been successful in examining certain of these areas and has resulted in the definition of some of the basic problem areas.

The employment of the three modes of experiment permits valid simulation and data accumulation for phenomena associated with ingress/egress, airlocks and passageways. Observation and analysis has shown that the water immersion mode yields the most useful data relative to the engineering aspects under study in this contract. In order to prove completely useful, however, reliance on the other two experiment modes is required in order to extend, validate and correlate the information derived from the water immersion experiments.

The water immersion mode is the most useful because of the ability to perform the simulated task in a real-time manner and further due to the unlimited spatial characteristics afforded.

Experiments performed using the aircraft mode are subjected to three inherent invalidating conditions. These are limited space to perform the mission properly, short duration of continuous 'Zero-gravity' and subject physical and mental stress attendant upon the initiation and cessation of the 'Zero-gravity' maneuver by the two and one half gravity pullouts. A number of experiments are necessary in this mode to aid in validation and correlation since this mode is the only mode in which true balanced gravity is attained both as affects external and internal manned performance.

The ground/normal gravity mode is useful in establishing operating procedures, estimating safety characteristics of the other modes and most importantly serves as a reproductable control for analytical treatment of data. A direct comparison between ground and space performance is not possible due to the different character of performance. This was demonstrated in Phase I particularly in the entry and exit task and also in the latching task. Extreme difficulty was experienced in the entry and exit task for subjects at greater than 2 PSIG. When no step-up was provided one subject was unable to complete the normal ingress/egress total--task at the 2 and 3 PSIG levels.

Underwater and in the aircraft the step height had no effect on performance since any subject orientation could be attained at will.

The reverse was true in the latching task. This task comprised the operation of the rotary latch configuration by a moderate level torque application to the hatch handle. Performance of this task in the ground/normal gravity mode was extremely simple requiring approximately 2-5 seconds. Aircraft and water immersion performance was considerably more complicated. Initial subject performance evidenced a counter-motion of the body in roll in response to the applied torque instead of the anticipated operation. The subject compensated for this absence of torque reaction by exercising the torque in a one-hand fashion while restraining his motion by grasping the latch hand hold with his free hand. Further difficulty was experienced when the subject was required to close the hatch. Closing the hatch requires the application of torque simultaneous with the termination of a pulling or thrusting motion necessary to close the hatch. The normal tendency of the subject was to thrust or pull the hatch until the stop was reached with a two--hand motion on the handles then release the handles and apply torque in a one-handed fashion. The small inherent spring-back, simulating the effect of an actual seal was sufficient to move the subject and the door to a position where the latches could not enter the latch seats. This procedure was sometimes repeated several times before a successful operation could be achieved.

The subject also evidenced a tendency toward soaring when exiting from the airlocks both in the water immersion and aircraft modes. This obviously, could not occur in the ground mode. The soaring was usually mitigated by the subject who used his trailing foot to arrest his motion. On several occasions the subject failed to arrest himself in this manner and became completely divorced from the airlock. In this condition he was completely helpless even though in relative close proximity to the airlock. His initial thrust caused a slight drift so that as time progressed his separation distance increased. When this occured the subject had to be assisted back to the airlock or the experiment was terminated. The subject commented that water drag did not appear significant and this was borne out by the analytical treatment of his drag relative to his velocity. Average velocities of approximately 0.5 feet per second were experienced during the ingress/egress maneuver.

In summary the following conclusions can be drawn from the Phase I experiements:

- Successful simulation of pressure-suited ingress/egress through airlocks and passageways is possible utilizing the three experiment modes, e.g. water immersion/neutral buoyancy, aircraft/balanced gravity and ground/normal gravity.

- Drag effects attendant upon operation in the water immersion mode are negligible because of low velocities and the restricted spatial requirements of airlock ingress/egress.

- Performance of subjects wearing full-pressure suits at pressures greater than 2 PSIG is significantly different in balanced gravity , 'Zero-gravity', than in normal gravity particularly as regards manner of task performance and spatial clearance requirements.

- A forty-eight inch diameter passageway approaches the minimum size if pressurized unassisted turn-around is required in the ingress/egress maneuver.

- Future experimentation of this type should rely most strongly on the water immersion/neutral buoyancy mode backed up by a reduced number of aircraft and ground experiments.

Recommendations and planning of the Phase II program and experiments is detailed in Appendix I.

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4. ''Dimensions of the Human Figure'', L.W. Sahley, Cleveland Designers and Consultants Inc., 1957

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6. ''Motion Performance of Pressure-Suited Subjects Under Zero and Lunar Gravity Conditions'', J.C. Simons, D.E. Walk, C.W. Sears, Presented at the Meeting of the Aerospace Medical Association, Miami, Florida, 12 May 1964

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8. ''Human Mechanics'', W.M. Krogman, F.E. Johnston, AMRL-RDR-63-123, Air Force Systems Command, December 1963

9. ''Aeronautical Systems Division Studies in Weightlessness'', L.R. Hammer, WADD TR 60-715, Aeronautical Systems Division, December 1961

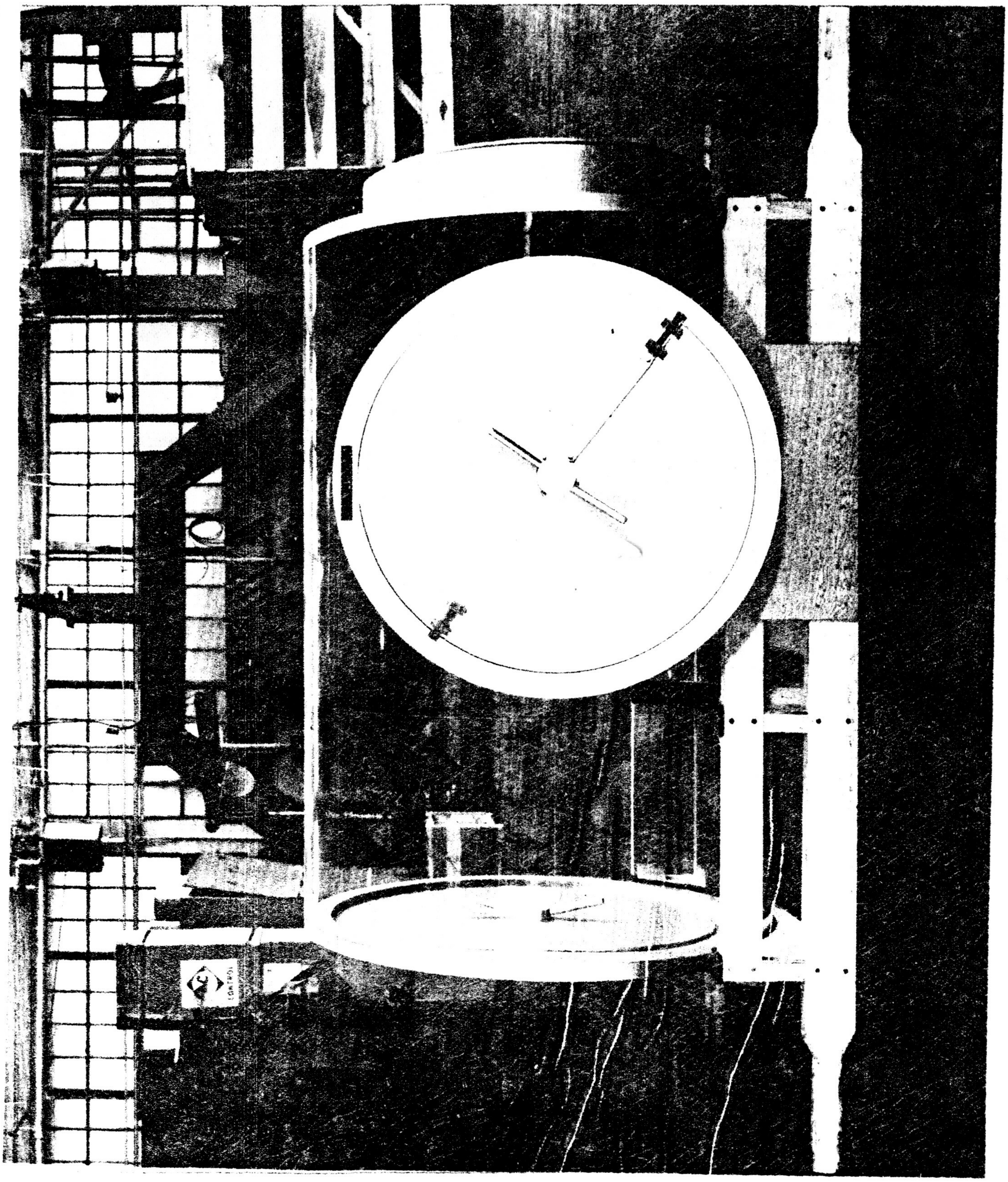


FIGURE 1 SIMULATED AIRLOCK

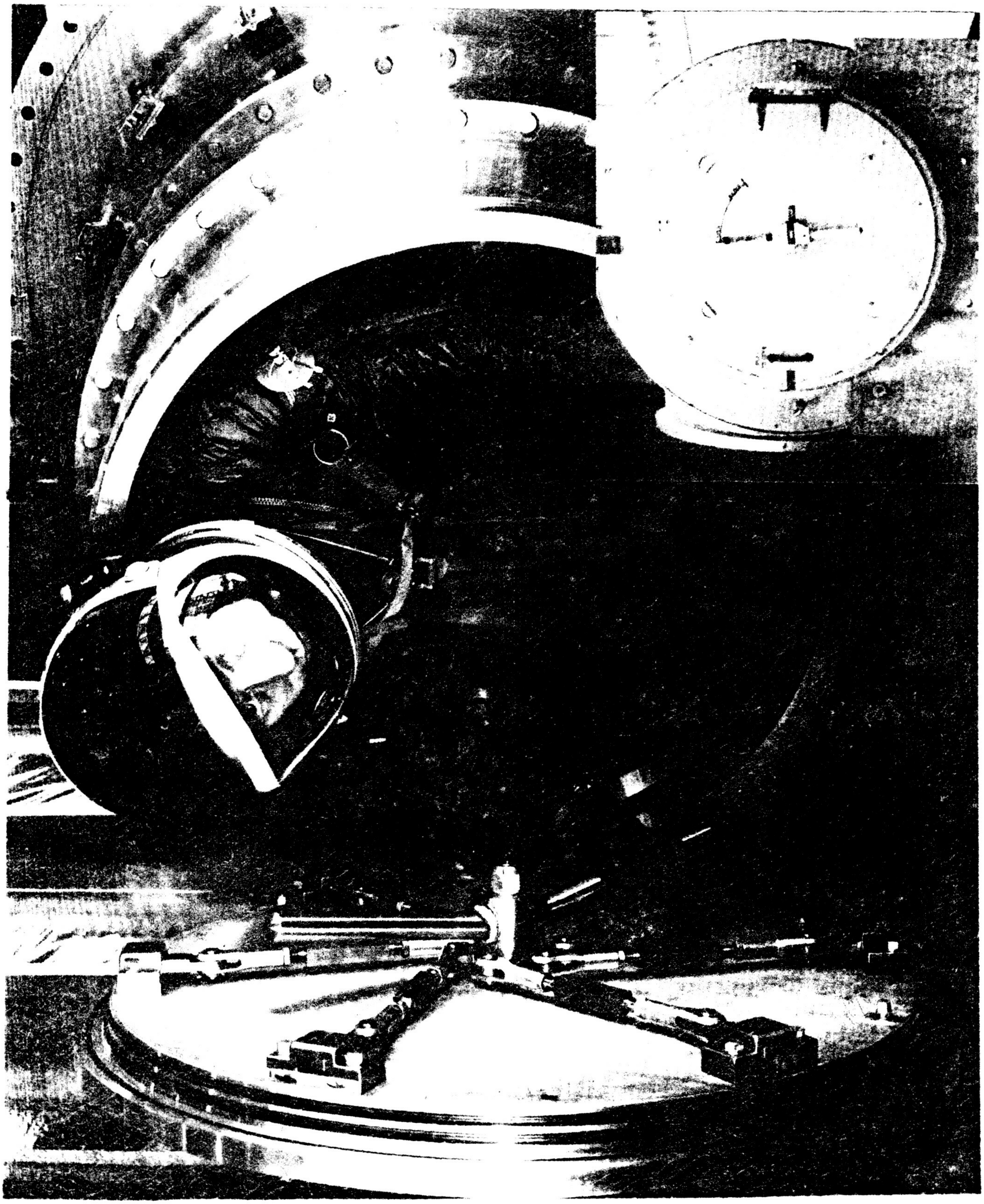


FIGURE 2 HATCH AND LATCHING CONFIGURATION - ACTUAL

FIGURE 3 LATCH CONFIGURATION - SIMULATED AIRLOCK

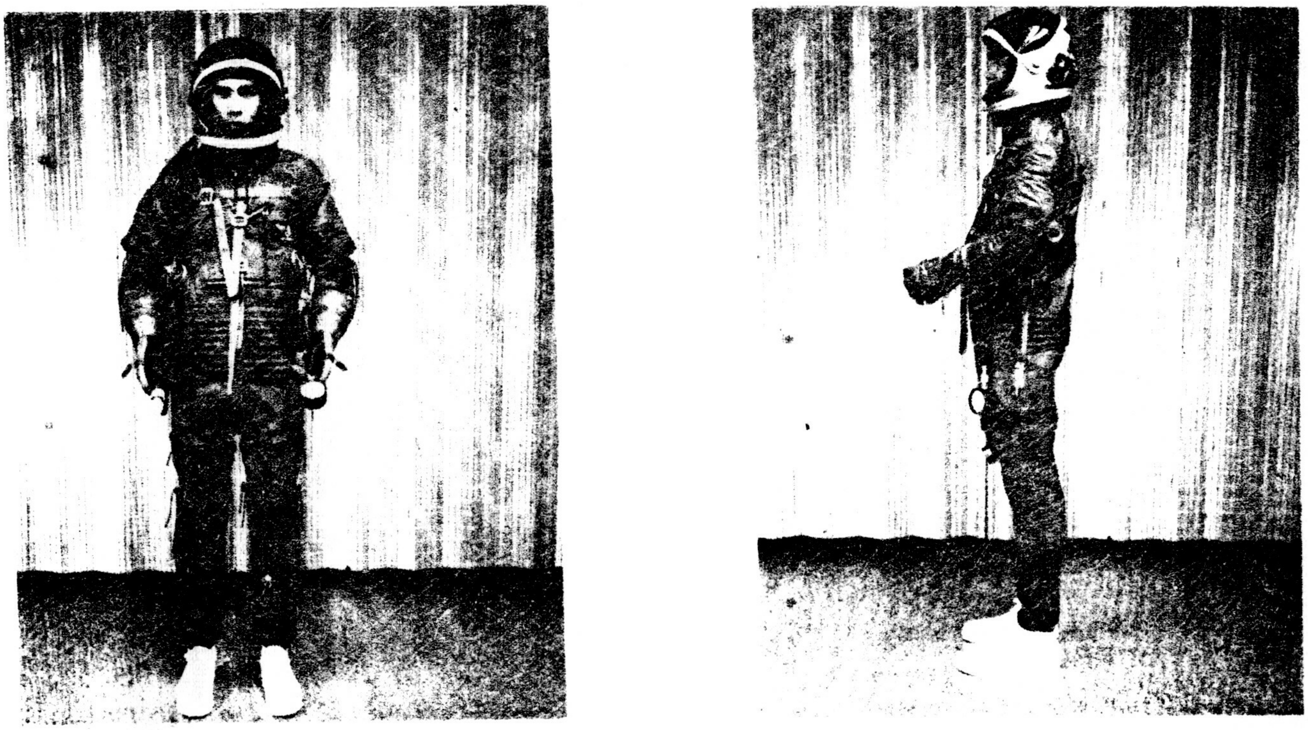


FIGURE 4 FULL PRESSURE SUIT - ARROWHEAD

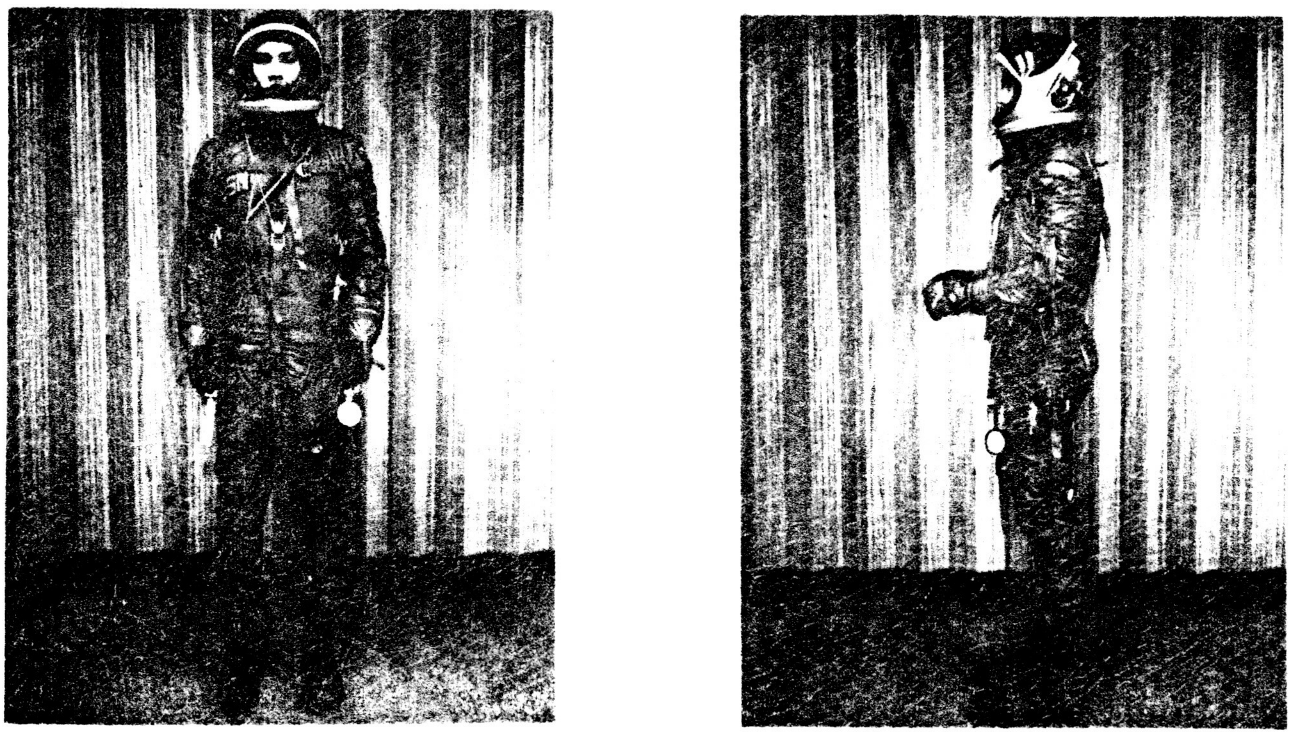


FIGURE 5 FULL PRESSURE SUIT - GOODRICH

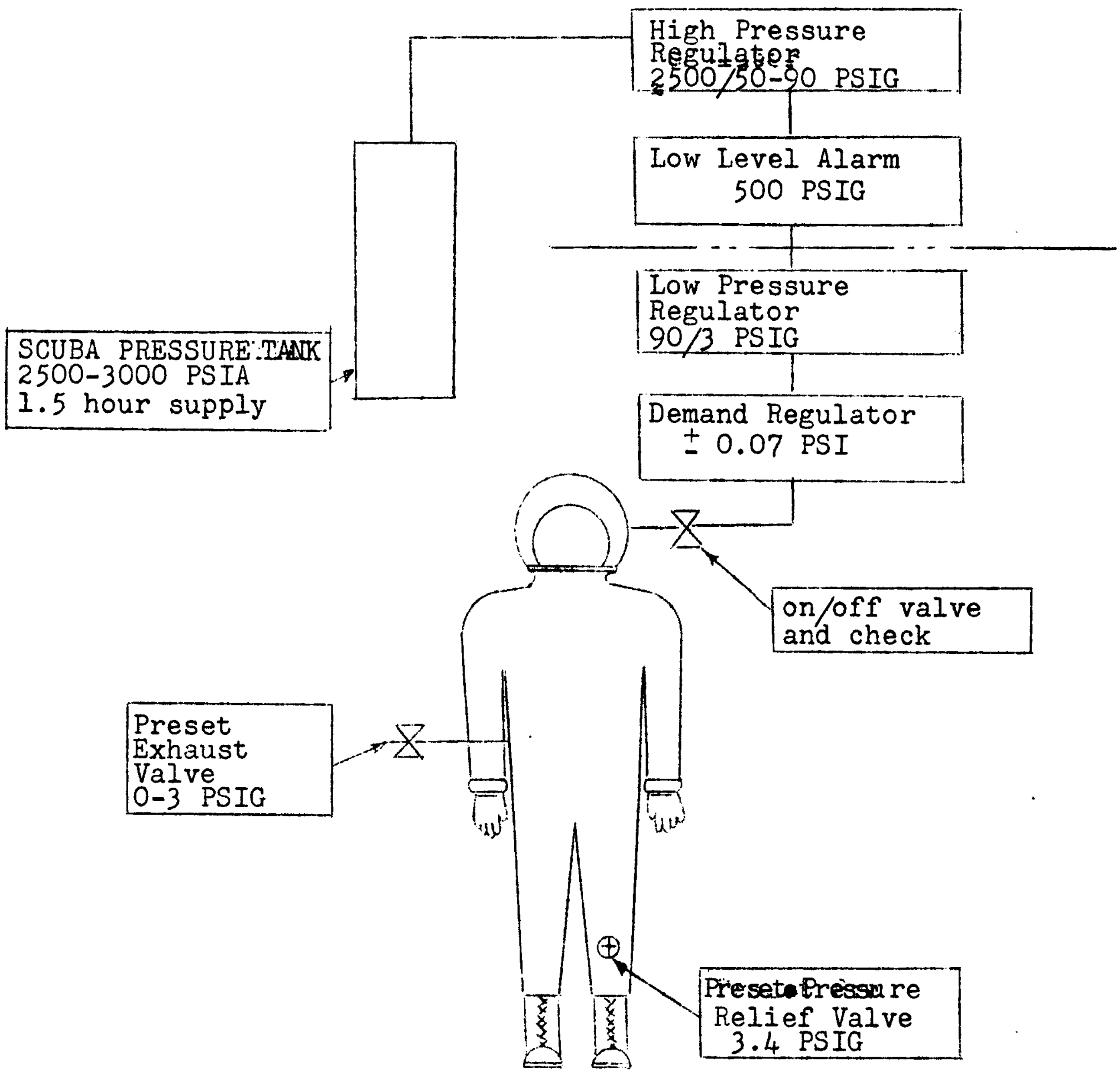


FIGURE 6 MODIFIED GAS PRESSURIZATION SYSTEM

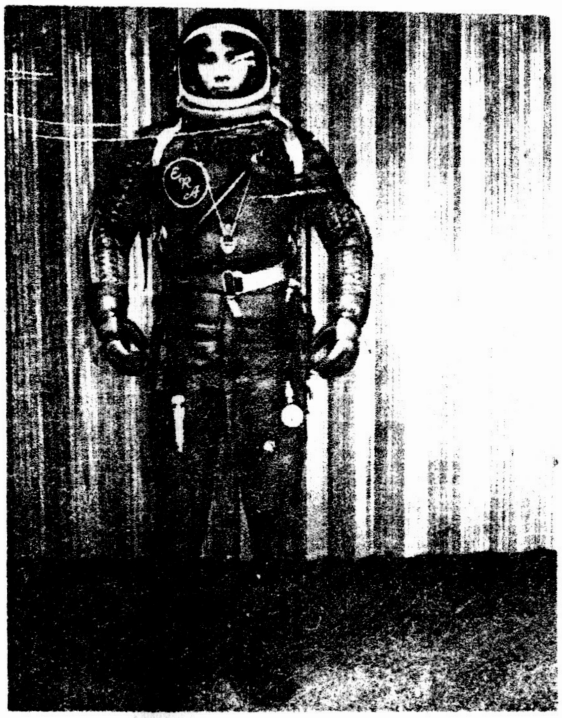


FIGURE 7 EXTERNAL VIEW OF MODIFIED GAS PRESSURIZATION SYSTEM

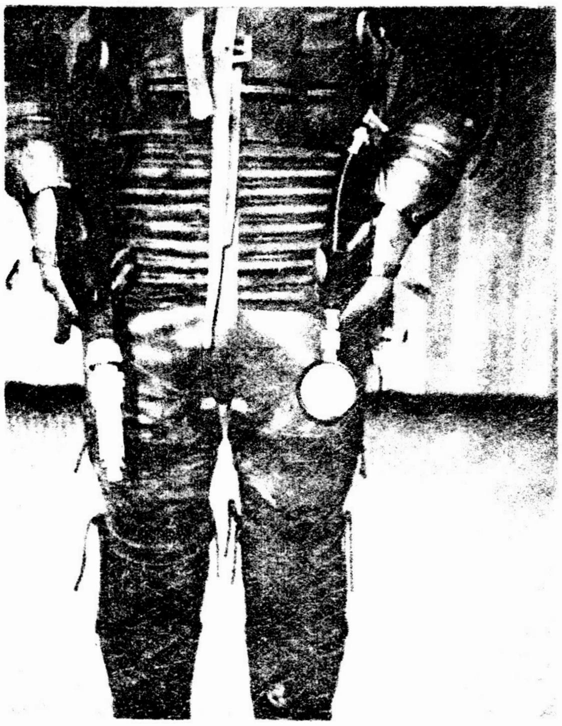


FIGURE 8 SUIT PRESSURE CALIBRATION UNIT

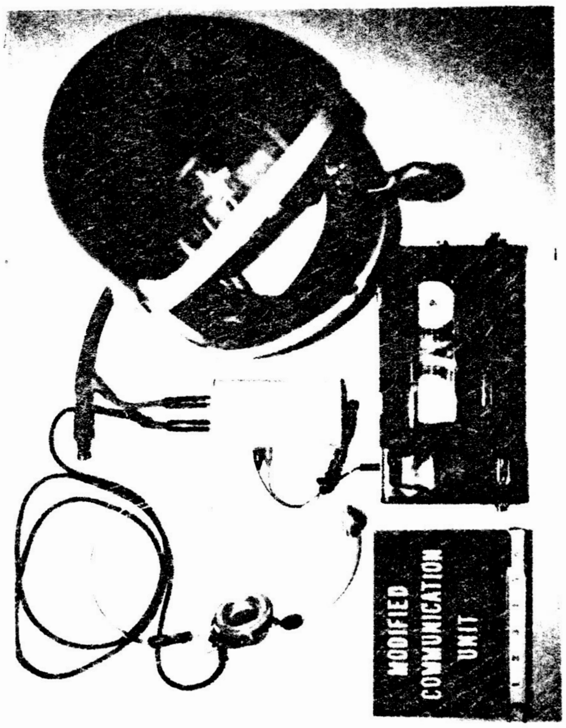


FIGURE 9 COMMUNICATION UNIT

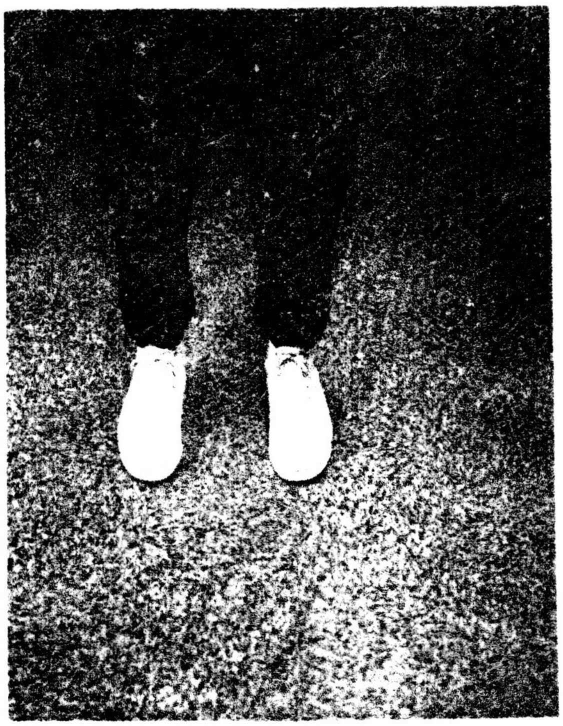


FIGURE 10 SUBJECT WITH FLEXIBLE ATHLETIC SHOES

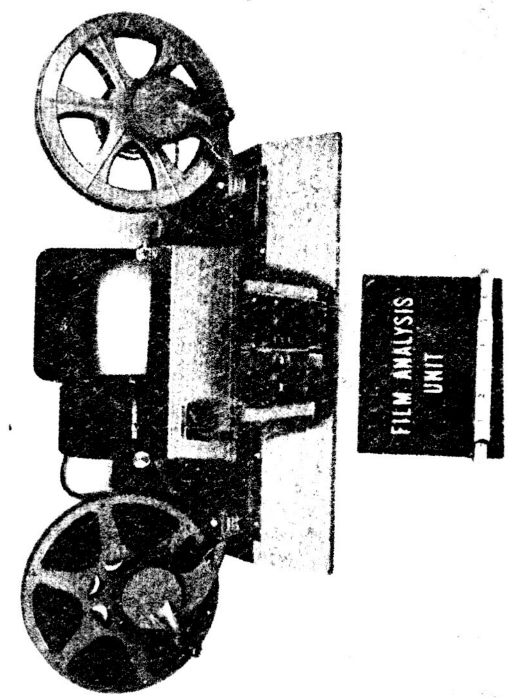


FIGURE 12 FILM ANALYSIS UNIT

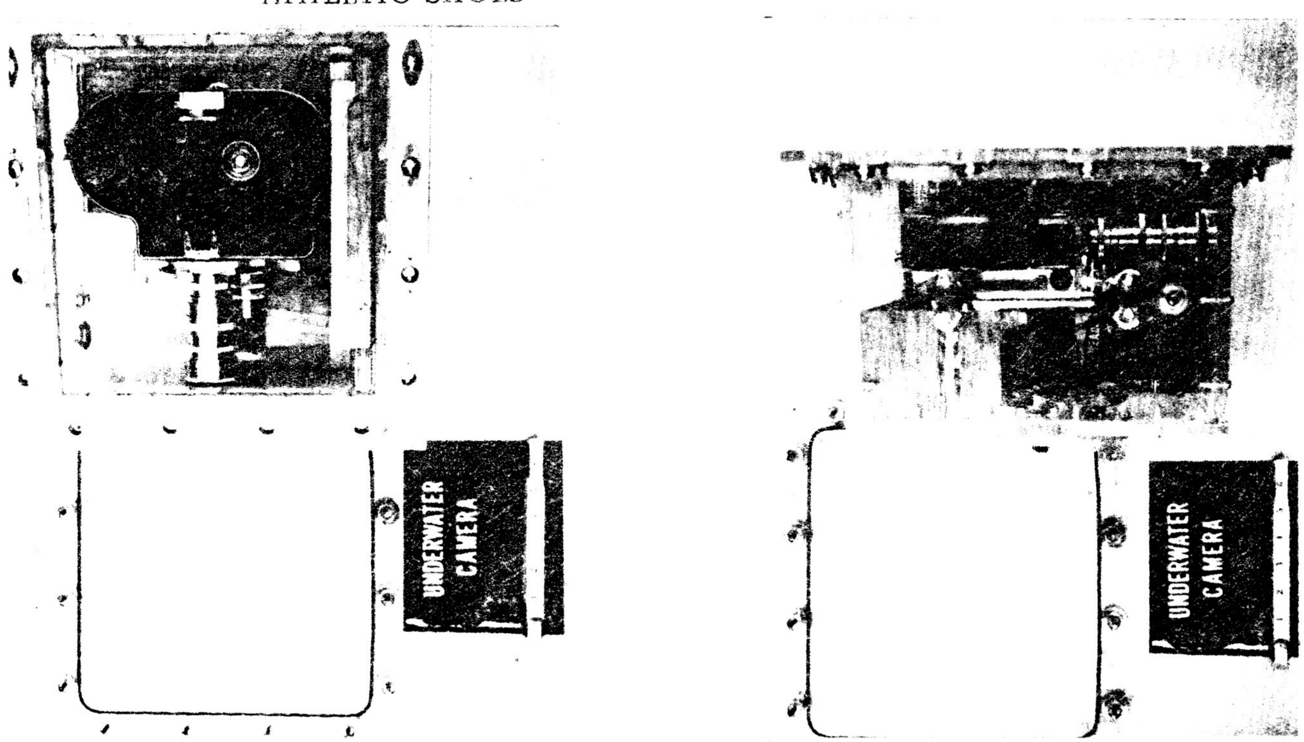


FIGURE 11 UNDERWATER CAMERA

FIGURE 13 SIMULATED
AIRLOCK
ELEVATED ENTRY

FIGURE 14

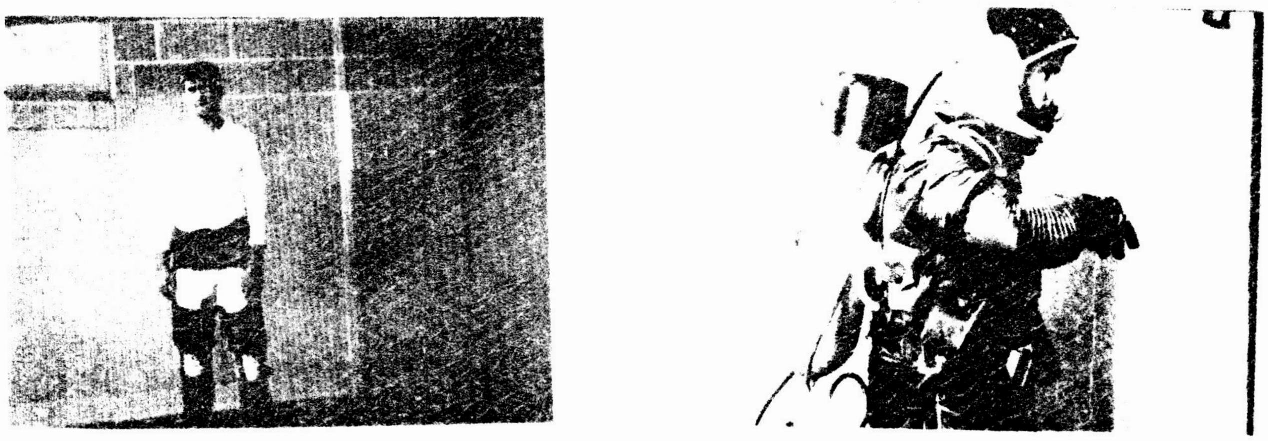


FIGURE 14 NEUTRAL BUOYANCY WEIGHTS

SUBJECT....................................Mattingly, G.S.

AGE..37

FLIGHT PHYSICAL STATUS.....................FAA/CLASS II

WEIGHT.....................................160 LBS.

HEIGHT.....................................70.5 IN.

<u>ANTHROPOMETRIC DATA</u>

HEIGHT.....................................70.5 IN.
WEIGHT.....................................160 LBS.
CERVICAL HEIGHT............................60 IN.
SHOULDER BREADTH...........................17 IN.
HIP BREADTH................................13.5 IN.
CHEST DEPTH................................10 IN.
HIP DEPTH..................................8.5 IN.
SHOULDER CIRCUMFERENCE.....................46 IN.
HIP CIRCUMFERENCE..........................40 IN.

FPS SIZE...................................MEDIUM LONG

FIGURE 15 ANTHROPOMETRIC DATA - G. SAMUEL MATTINGLY

Environmental Research Associates

FLIGHT TRAINING CERTIFICATION

This certifies that

MR. G. SAMUEL MATTINGLY

became a member of SPACE on 2nd (day) JUNE 19 64.

FULL PRES. SUIT INDOCT. WITH EXPL. DECOMP. MAX. ALT. 70,000

SIGNATURE C. C. COLE LT MSC USN

SPACE CERTIFICATE

UNITED STATES OF AMERICA
FEDERAL AVIATION AGENCY

MEDICAL CERTIFICATE Second **CLASS**

THIS CERTIFIES THAT: *(Full name and address)*

MATTINGLY, George Samuel
118 Charmuth Road
Timonium, Maryland

Date of Birth	Height	Weight	Hair	Eyes	Sex
10 Aug.26	70 3/4 IN.	159 1/2	Ltbr	blue	male

has met the physical standards prescribed in Part 29, Civil Air Regulations, for this class of Medical Certificate.

LIMITATIONS

None

Date of examination	Examiner's Serial Number
12 August 1964	ATR 1344-34-1

Examiner Signature

Typed Name Theodore L. Light, M.D.

Airman's Signature

Form FAA 1004.1 (5-61)

PHYSICAL EXAMINATION FOR FLYING

NAME		GRADE	AFSN	ORGANIZATION	AERO RATING
Mattingly G. Samuel		Civ	-	ASD	
DATE	**STATION**	**RESULT**	**CLASS**	**SIGNATURE OF FLIGHT SURGEON**	
16 Jul 63	WP AFB, OHIO	Q	III	P. F. Nugent Maj USAF MC SFS	

ALTITUDE INDOCTRINATION				MISCELLANEOUS TRAINING
DATE	**STATION**	**TYPE**	**SIGNATURE**	
16 AUG 1963	WPAFB, Ohio	Pressure Rapid Decompression		Sur Trng 17 Jul 63 MSgt USAF
JUN 2 1964	FULL PRES. SUIT INDOCT. WITH EXPL. DECOMP. MAX. ALT. 70,000		FPSTU MED. DEPT. USNAS, NORVA	C. C. COLE LT MSC USN

AUTHORITY TO PARTICIPATE IN AFSC TEST AIRCRAFT			
DATE	**STATION**	**APPROVED BY**	**EXPIRATION DATE**
14Aug64	WPAFB, Ohio	Richard P. Chant, MD, USAF	2 Jun 65

FIGURE 15 (CONT.) ANTHROPOMETRIC DATA - G. Samuel Mattingly

SUBJECT....................................Franz, W.J.

AGE..19

FLIGHT PHYSICAL STATUS.....................FAA/CLASS II

WEIGHT.....................................182 LBS.

HEIGHT.....................................70 IN.

ANTHROPOMETRIC DATA

HEIGHT.....................................70 IN.
WEIGHT.....................................182 LBS.
CERVICAL HEIGHT............................59 IN.
SHOULDER BREADTH...........................18 IN.
HIP BREADTH................................14 IN.
CHEST DEPTH................................9 IN.
HIP DEPTH..................................9.5 IN.
SHOULDER CIRCUMFERENCE.....................46 IN.
HIP CIRCUMFERENCE..........................42 IN.

FPS SIZE...................................MEDIUM LONG

FIGURE 16 ANTHROPOMETRIC DATA- W. FRANZ

EXPERIMENT DATA SHEETS Figure 17

Suit/Dir/Psi/Run	Sub-Task Number A	B	C	D	E	F	G	Total Time
AH/O-C/3/G-1	8.75	20.50	15.05	6.37	3.00	61.44	#	
AH/O-C/2/G-2	3.06	16.44	7.75	4.87	4.81	38.88	#	
AH/O-C/1/G-3	2.44	10.50	6.94	6.56	2.31	4.13	#	
AH/C-O/1/G-4	4.31	10.50	3.87	2.25	2.50	13.65	3.87	40.95
AH/O-C/O/G-5	1.50	5.50	2.25	1.44	1.50	5.37	3.37	20.93
AH/C-O/O/G-6	2.75	4.12	3.31	1.56	2.00	5.75	2.81	22.30
CA/O-C/O/G-7	1.56	2.69	3.25	.94	2.00	1.88	2.50	14.82
GA/C-O/O/G-8	2.31	1.81	2.06	.56	3.38	2.56	3.00	15.68
G/c-O/3/G-9	4.8	17.6	21.6	12.2	5.8	17.9	14.2	94.1
G/O-C/3/G-10	3.2	22.3	15.3	8.2	4.8	19.7	24.8	98.3
G/C-O/2/G-11	3.3	13.5	20.9	8.3	5.9	12.7	8.1	72.7
G/O-C/2/G-12	3.8	19.0	7.8	8.5	3.6	15.2	14.0	71.9
G/C-O/1/G-13	2.9	10.8	10.8	5.8	3.8	11.4	5.0	50.5
G/O-C/1/G-14	0.9	10.8	5.4	4.1	3.5	10.5	7.5	42.7
G/C-O/O/G-15	4.6	7.1	10.4	5.0	1.6	7.7	4.7	41.1
G/O-C/O/G-16	1.8	5.4	4.3	2.9	3.5	11.3	3.3	32.5
CA/C-O/O/G-17	1.9	2.2	1.9	1.5	1.7	2.1	1.6	12.9
CA/O-C/O/G-18	1.1	2.3	1.9	2.2	0.8	2.0	2.3	12.6
CA/C-O/O/G-19	1.4	1.3	1.7	1.5	1.5	2.2	1.5	11.1
CA/O-C/O/G-20	1.1	1.6	1.8	1.0	0.9	2.1	2.5	11.0
AH/C-O/3/G-21	4.3	10.9	9.6	6.2	2.4	3.9	9.3	46.6
AH/O-C/3/G-22	2.4	11.8	9.8	5.9	2.2	21.0	5.7	58.8
AH/C-O/2/G-23	3.6	10.7	7.2	4.9	2.9	10.0	5.9	45.2
AH/O-C/2/G-24	2.3	9.5	6.4	2.9	3.0	13.5	10.4	48.0
AH/C-O/1/G-25	3.2	9.1	7.4	5.7	2.5	2.9	5.9	36.7
AH/O-C/1/G-26	2.3	7.4	3.0	2.8	1.4	11.0	3.2	31.1
AH/C-O/O/G-27	1.0	5.7	4.8	1.8	1.8	7.3	6.3	28.7
AH/O-C/O/G-28	1.5	4.9	5.0	2.2	1.4	5.1	4.3	24.4

NOTES: Times were calculated from motion picture reels numbered 6 and 7 using editor and frame counter. All the above runs were ground runs.

FINAL EXIT NOT COMPLETED DURING THIS RUN

Runs G-1 through G-8 were made on 7-16-64.
Runs G-9 through G-20 were made on 7-29-64
Runs G-21 through G-28 were made on 7-30-64

AH/C-O/3.5/GL-1	10.7	16.9	71.5	20.9	11.8	7.4	12.9	152(4)
AH/O-C/3.5/GL-2	23.6	38.8	63.7	12.3	23.2	27.2		189(5)
AH/C-S/3.5/GL-3	23.7	28.9	54.9	18.2	22.5	41.4	46.0	236(6)
G/C-O/2/GL-4	4.7	13.3	32.0	.3	12.2	11.0	13.2	87
G/O-C/2/GL-5	5.1	13.2	16.7	11.7	3.2	11.6		62(7)
G/C-O/2/GL-6	3.3	11.1	21.3	15.3	3.7	45.6	9.0	109(8(
G/O-S/2/GL-7	3.0	7.7	15.5	6.8	17.1	44.3	17.5	112
G/S-C/2/GL-8	9.9	12.5	34.1	20.0	3.8			80(9)

NOTE: 1. Runs GL-1 through GL-3 were from reel No. 3 with Mattingly as subject on 6-18-64.
2. Runs GL-4 through GL-8 were from reel No. 5 with Kent as subject on 4-38-64.
3. All the above runs were made on 4-28-64 at Langley, Virginia

Figure 17
(Cont.)

NOTES: (Cont.)

4. Sub-Task G is approximate
5. Sub-Task G is not completed
6. Exit in this run was to side door
7. Sub-Task A and C are approximate.
8. Sub-Tasks F and G are approximate.
9. Sub-Tasks F and G are not completed.
10. Times were calculated from motion picture films using editor and frame counter.

AH/C-O/2/UW-1	27.2	27.5	31.6	17.6	10.8	14.6	27.2	156.5
AH/O-C/2/UW-2	11.2	26.0	38.1	19.6	10.3	13.3	27.2	145.7

NOTE: The times for sub-tasks for underwater runs UW-1 and UW-2 are a composite of sub-task times for several incomplete runs.

AH/O-C/1/A-1	2.9	4.8	10.2	8.5	11.8	8.8	5.3	
AH/C-O/1/A-2	--	--	--	--	5.1	3.3	5.1	
AH/O-C/1/A-3	6.3	6.3	5.9	7.8	--	--	--	
AH/C-O/1/A-4	--	--	--	--	8.0	4.2	6.2	
TOTAL	9.2	11.1	16.1	16.3	24.9	16.3	16.6	
AVERAGE	4.6	5.6	8.1	8.2	8.3	5.1	5.5	45.4

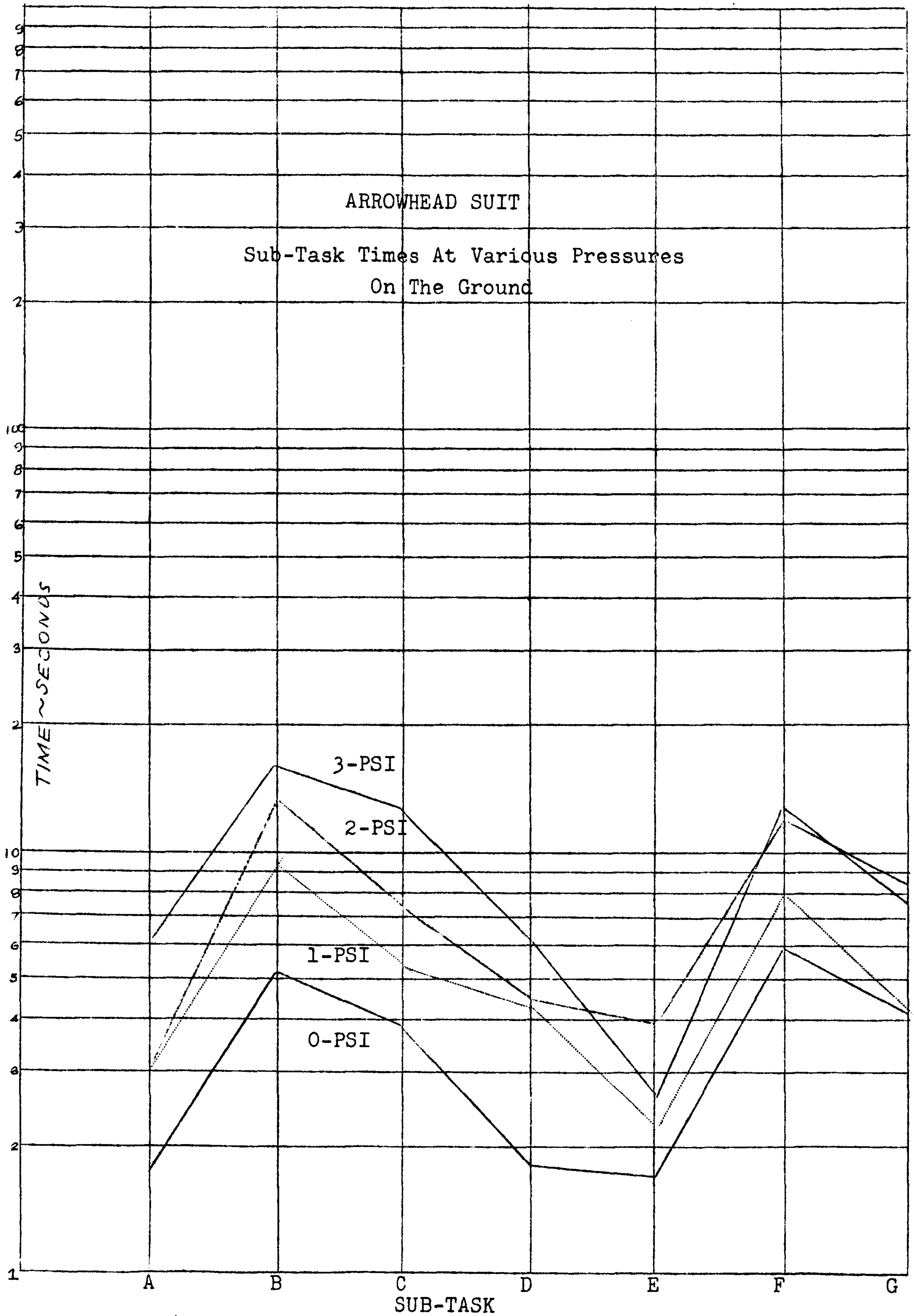

ARROWHEAD SUIT
Sub-Task Times At Various Pressures
On The Ground
TIME ~SECONDS
3-PSI
2-PSI
1-PSI
0-PSI
A
B
C
D
E
F
G
SUB-TASK

FIGURE 18

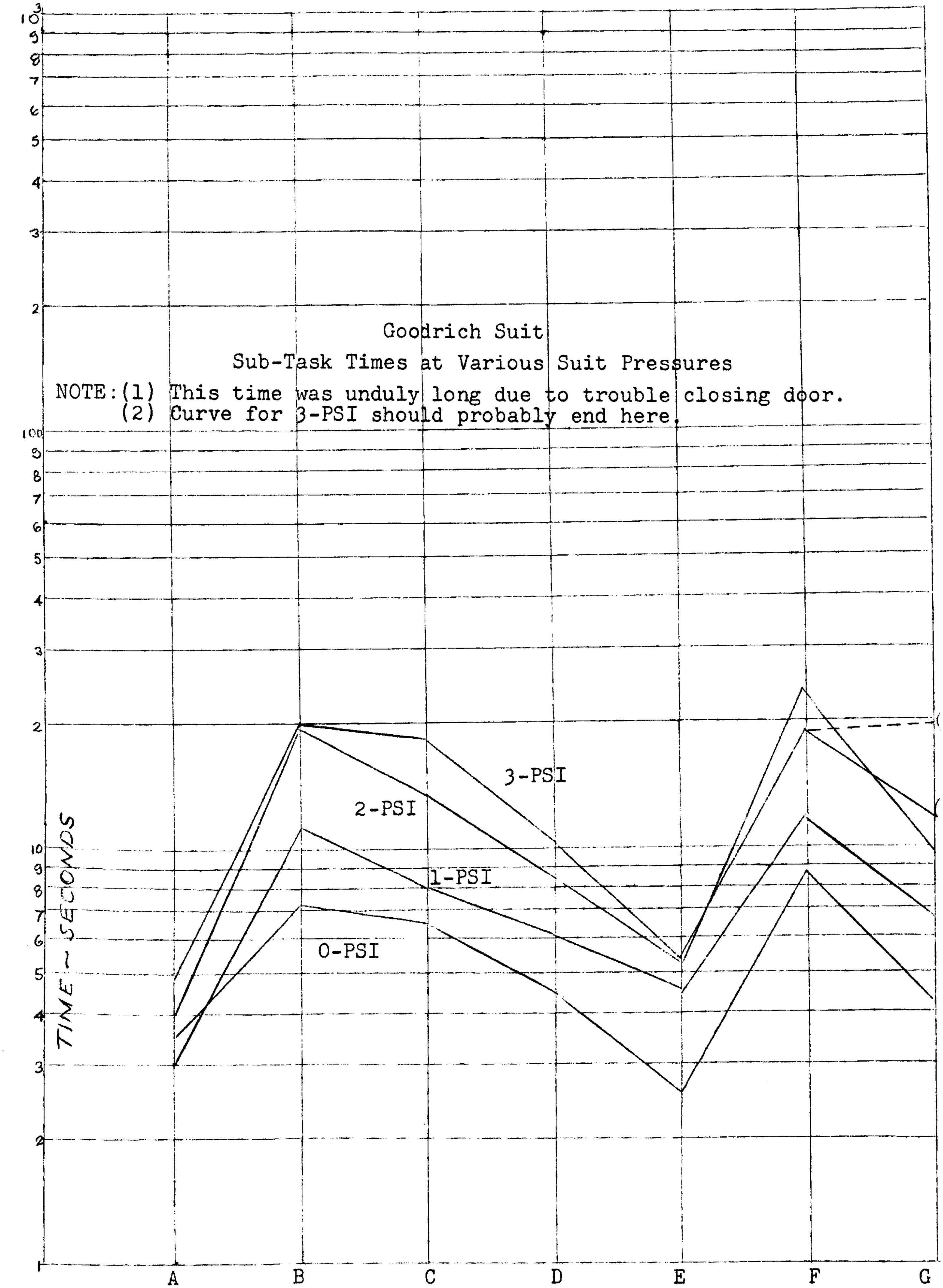
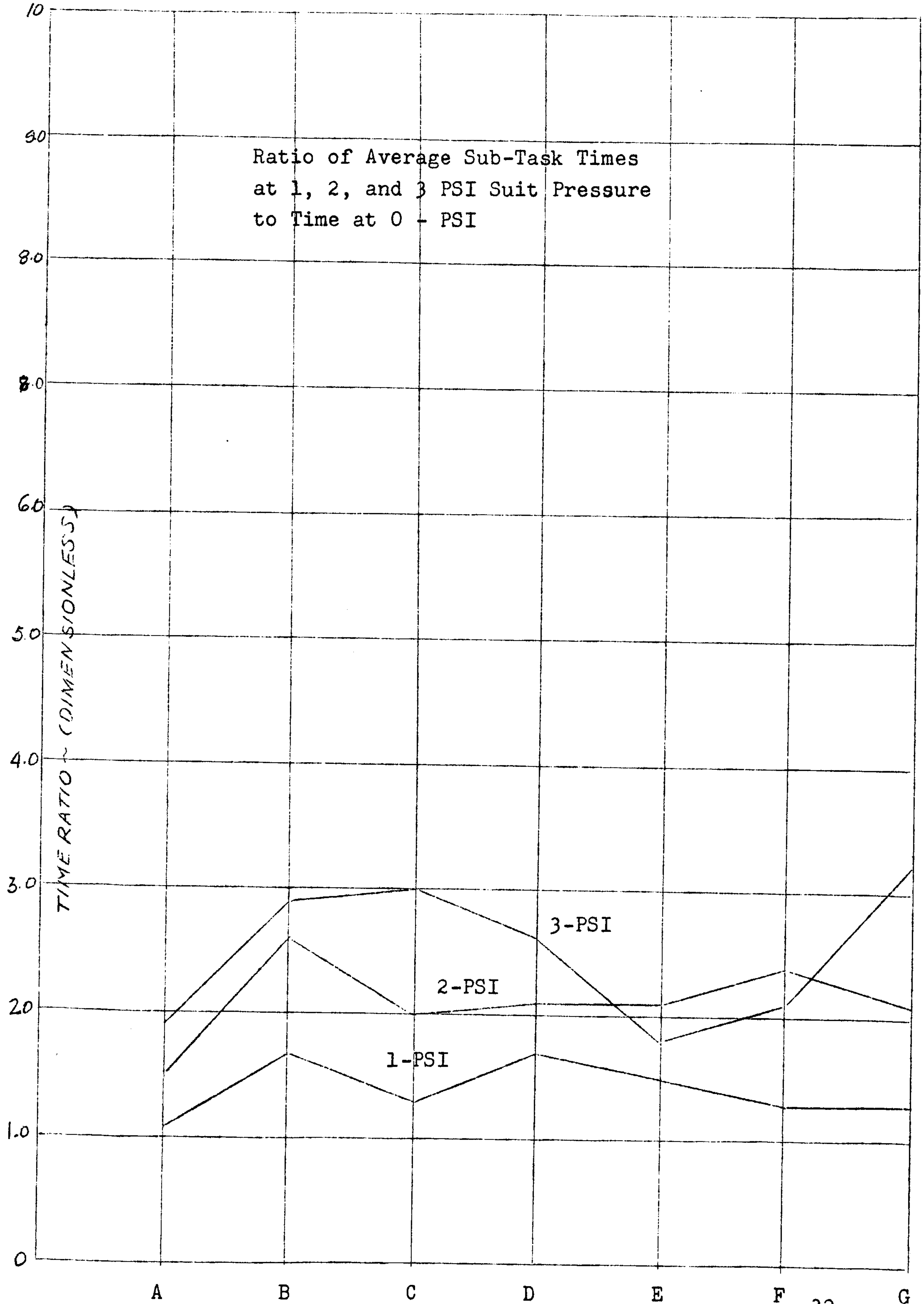


FIGURE 19 SUB-TASK


Ratio of Average Sub-Task Times
at 1, 2, and 3 PSI Suit Pressure
to Time at 0 - PSI
TIME RATIO ~ (DIMENSIONLESS)
10
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
3-PSI
2-PSI
1-PSI
A
B
C
D
E
F
G
FIGURE 20

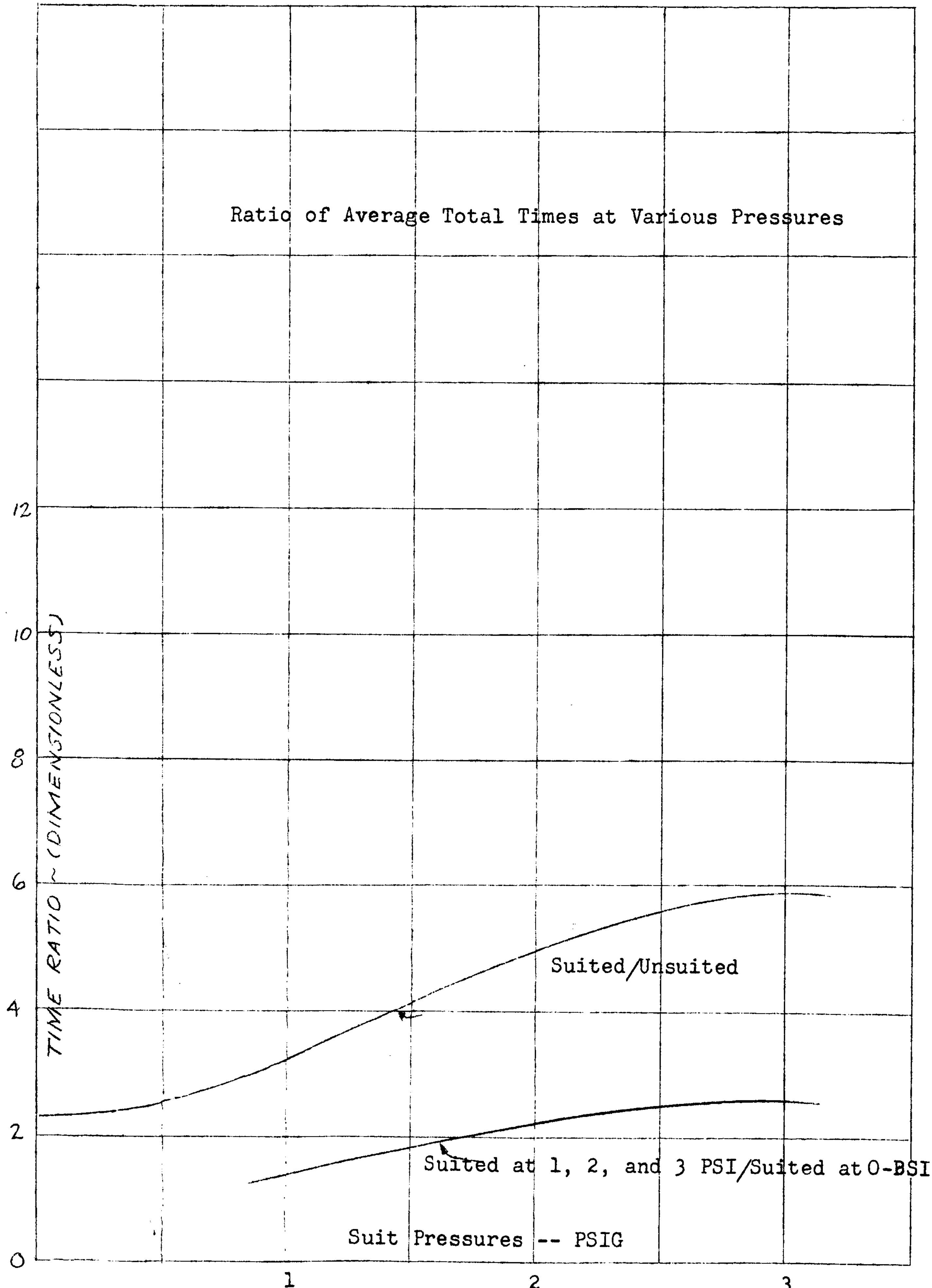
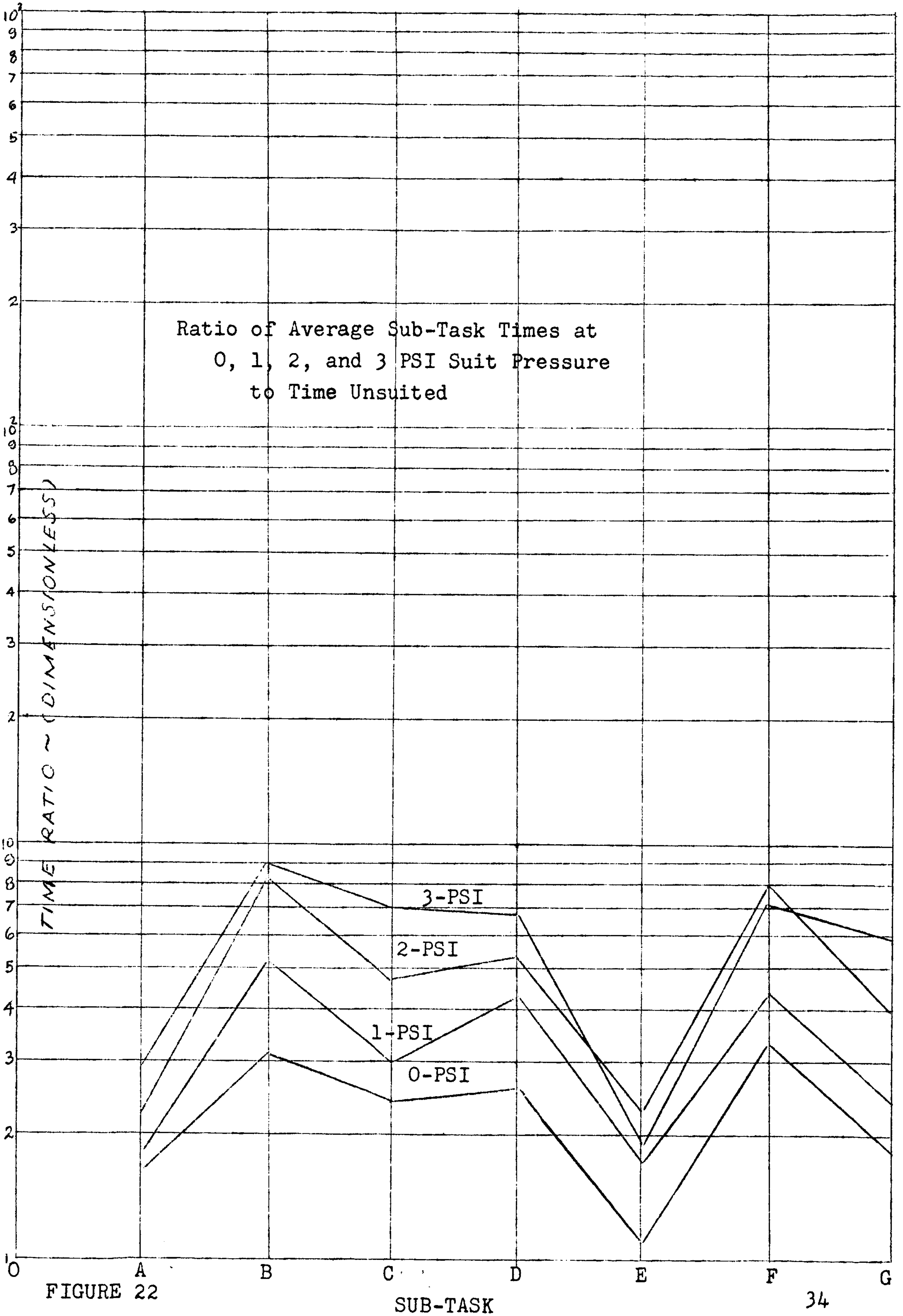

Ratio of Average Total Times at Various Pressures
12
10
8
6
4
2
0
TIME RATIO ~ (DIMENSIONLESS)
Suited/Unsuited
Suited at 1, 2, and 3 PSI/Suited at 0-BSI
Suit Pressures -- PSIG
1
2
3

FIGURE 21



10^3
9
8
7
6
5
4
3
2
Ratio of Average Sub-Task Times at
0, 1, 2, and 3 PSI Suit Pressure
to Time Unsuited
10^2
9
8
7
6
5
4
3
2
TIME RATIO ~ (DIMENSIONLESS)
10
9
8
7
6
5
4
3
2
1
3-PSI
2-PSI
1-PSI
0-PSI
O
A
B
C
D
E
F
G
SUB-TASK

FIGURE 22

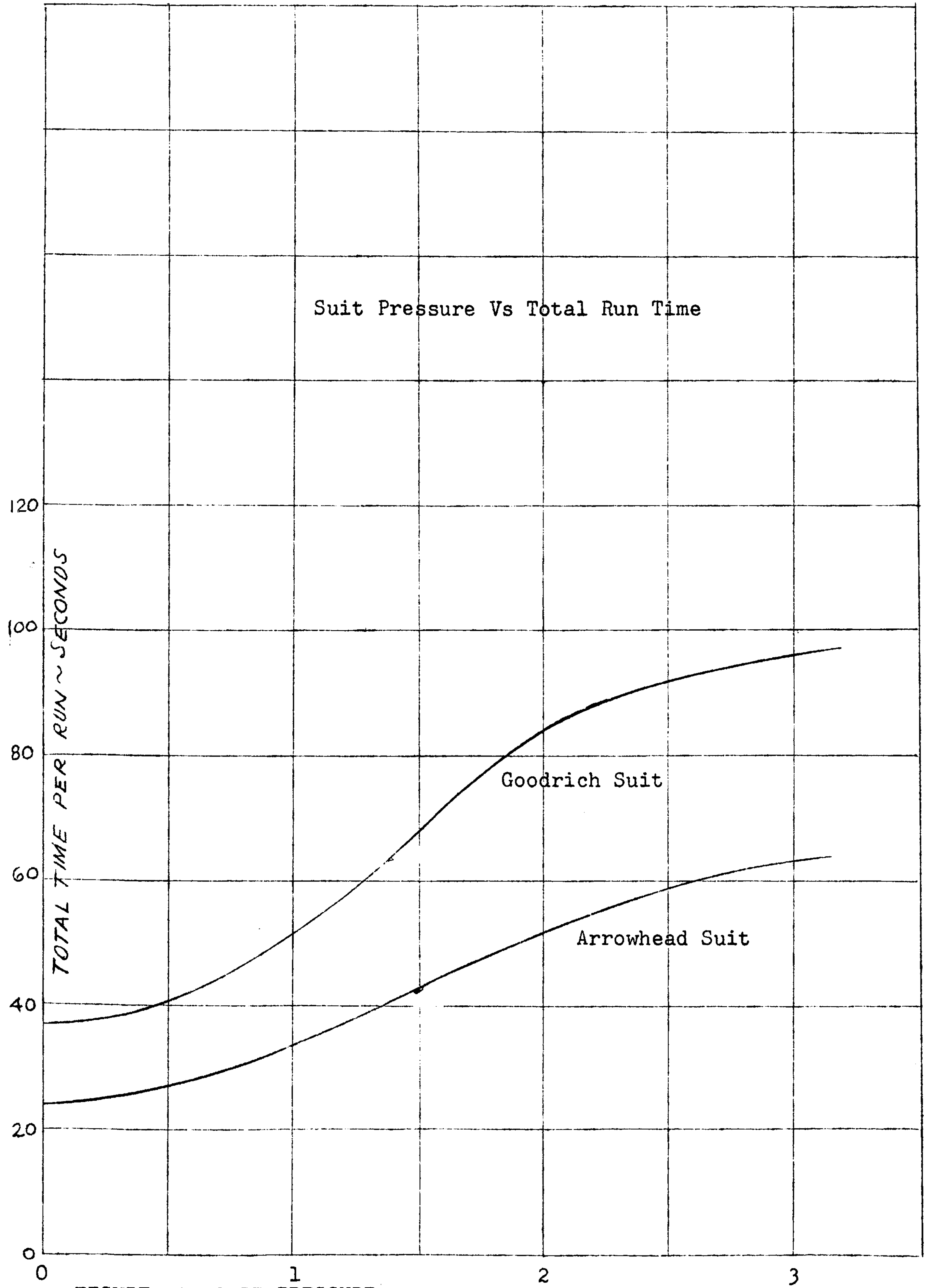


FIGURE 23 SUIT PRESSURE

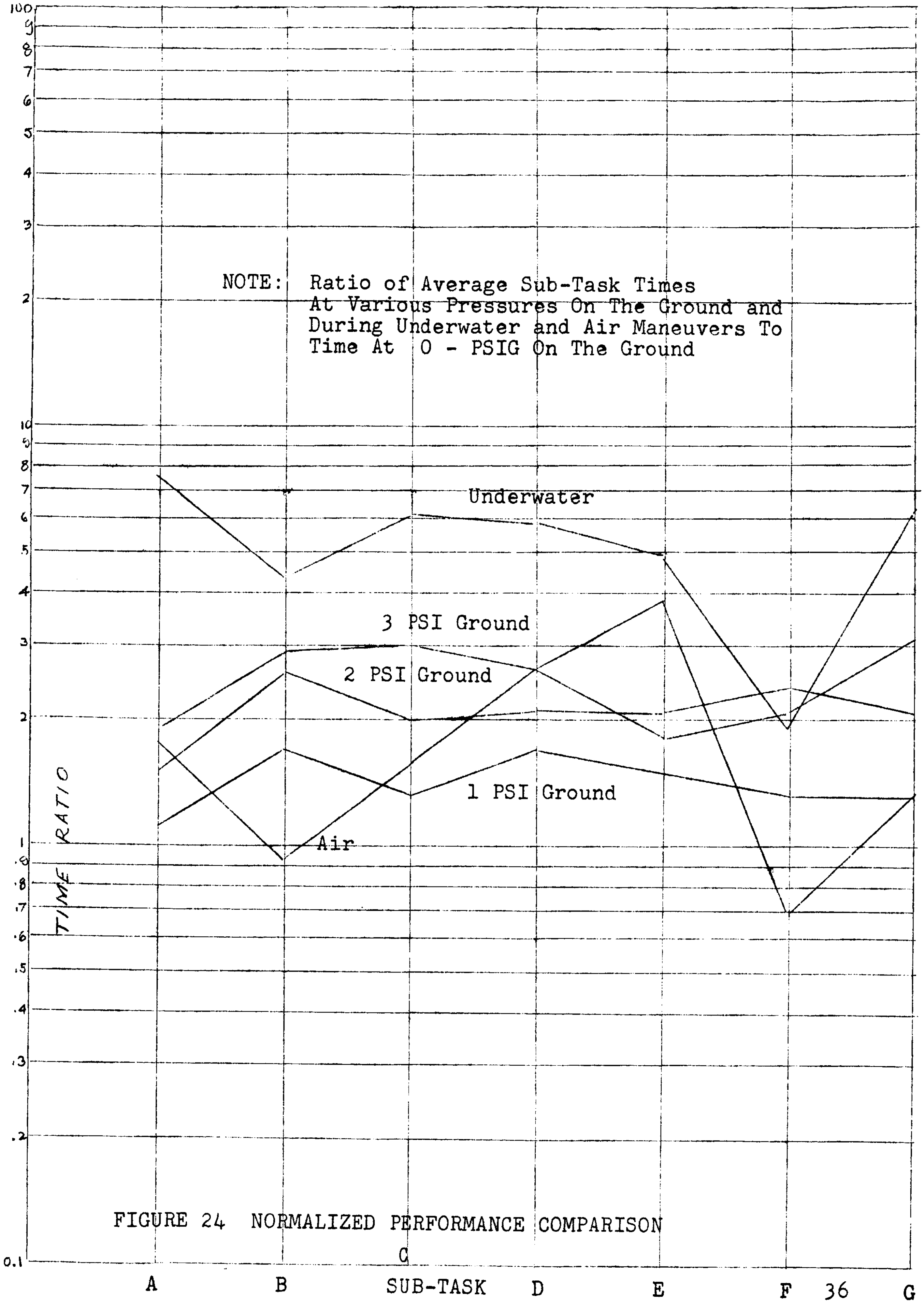


FIGURE 24 NORMALIZED PERFORMANCE COMPARISON

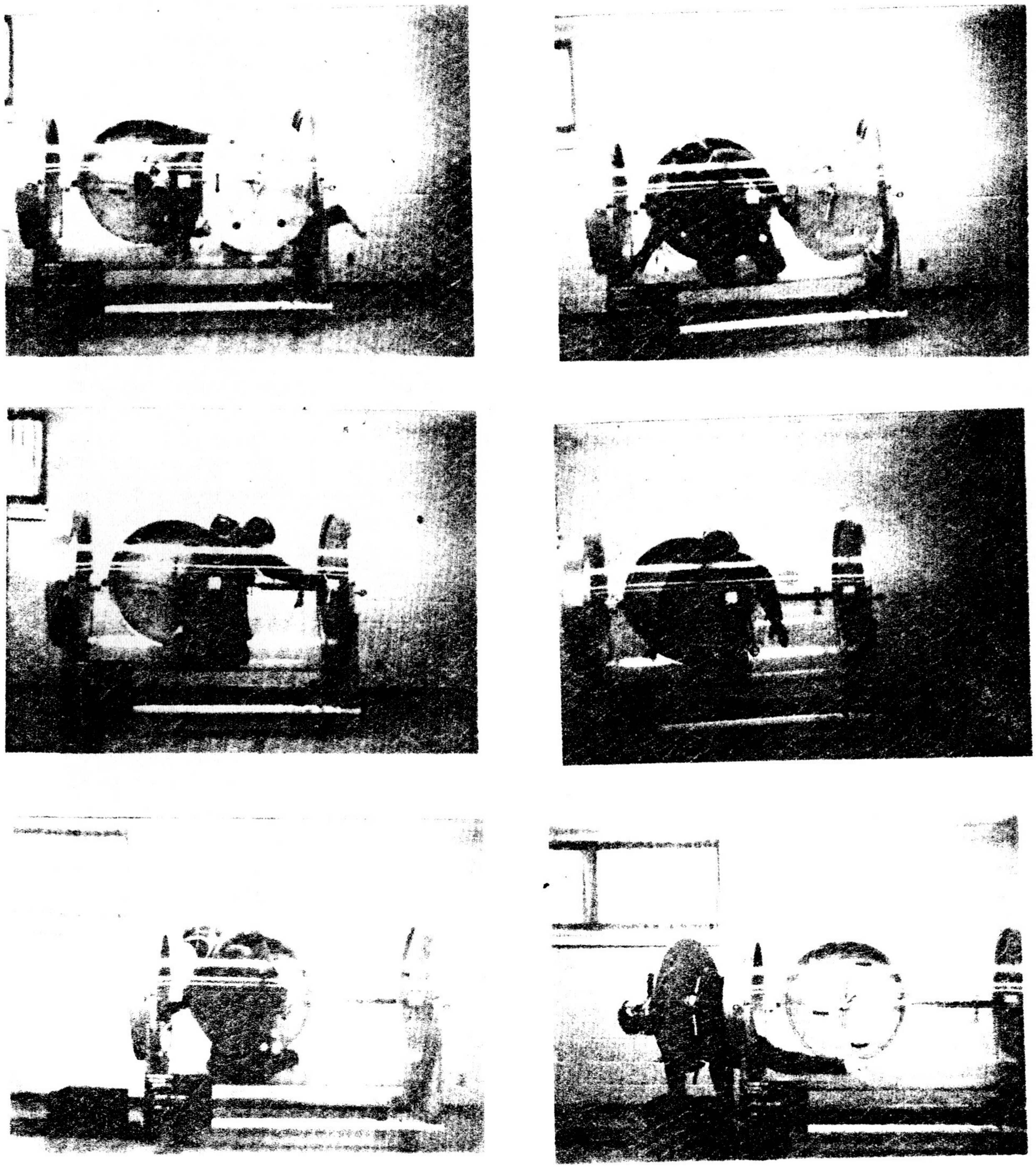


FIGURE 25 GROUND/NORMAL GRAVITY MODE

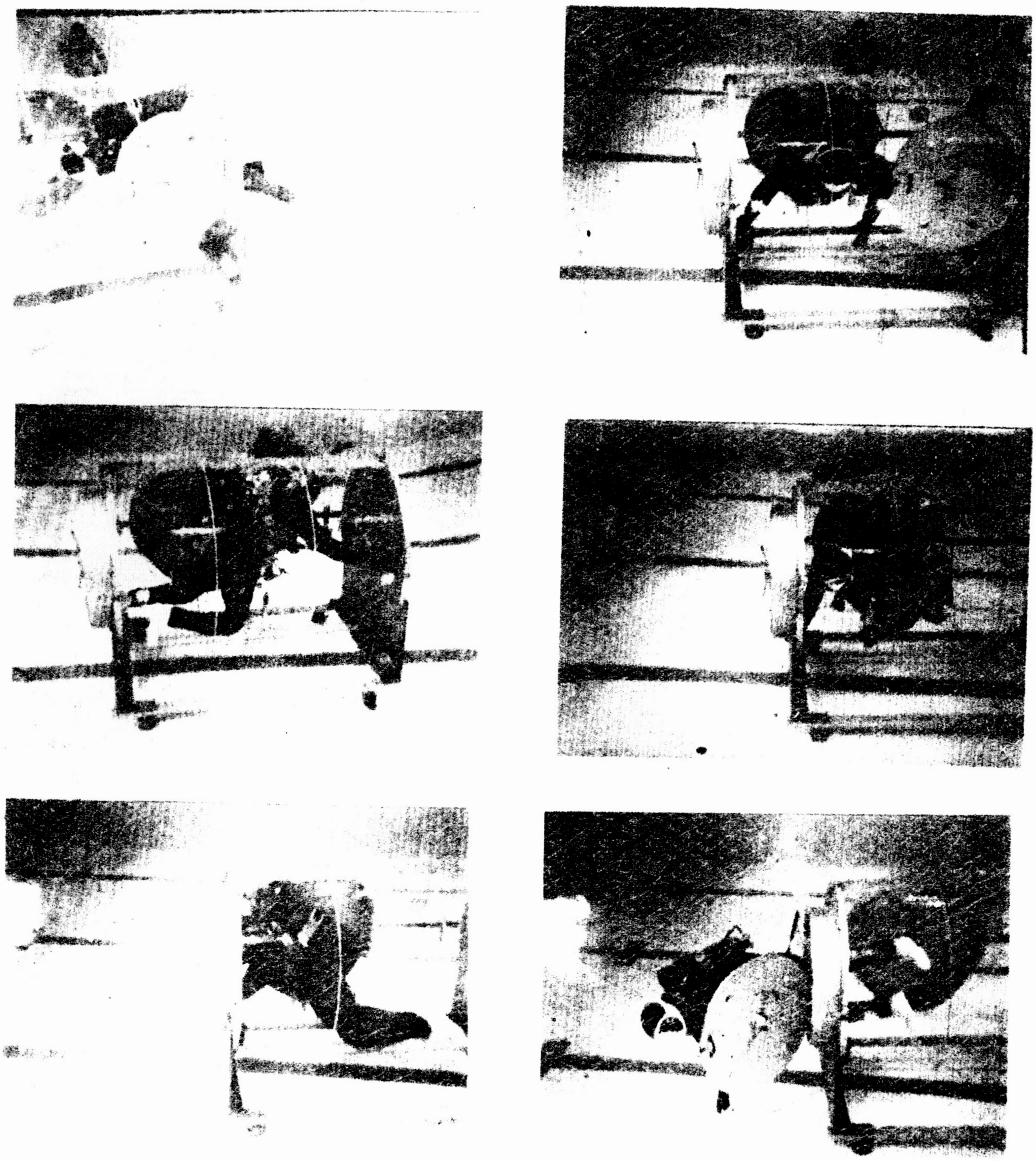
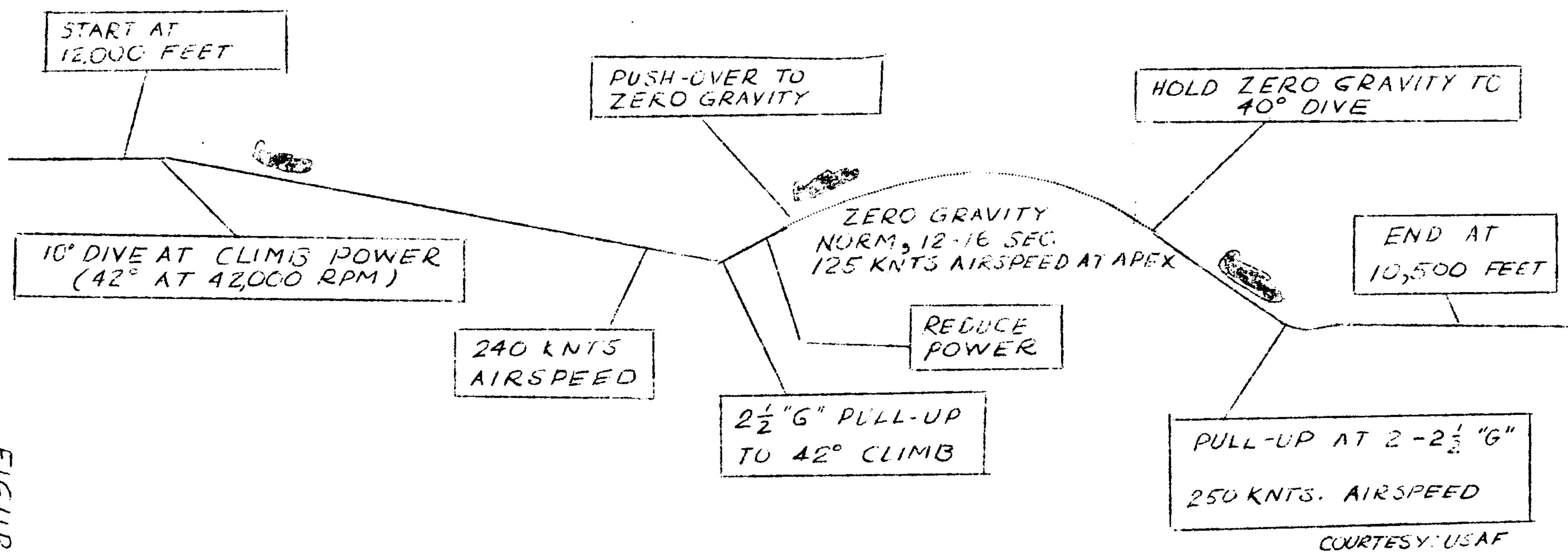


FIGURE 26 WATER IMMERSION/NEUTRAL BUOYANY MODE

FIGURE 27 AIRCRAFT/BALANCED GRAVITY MODE

C - 131 B

ZERO GRAVITY PARABOLA



FIGURE~28

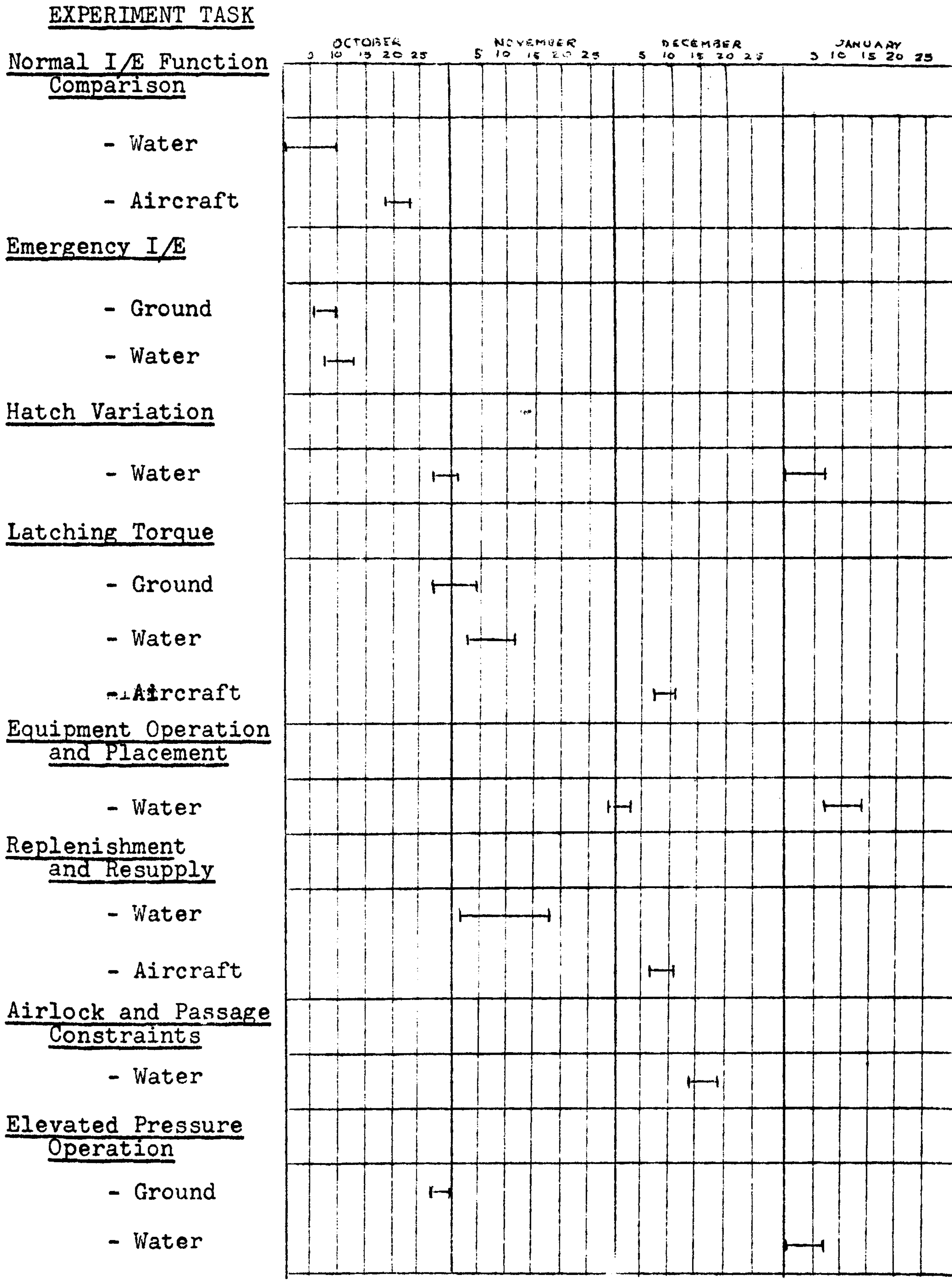


FIGURE 29 PHASE I - EXPERIMENT SCHEDULE

TABLE I - AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	Airlock/Ingress and Egress
Equipment	Airlock, hatches, full pressure suit, self contained breathing equipment
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Suit relief pressure gauge, suit pressure supply indicator
Diagnosis and Decisions	Recognizes airlock, suit,hatches in visual working order, preliminary to ingress/egress
Action	Approaches hatch
Feedback	Visual proximity of hatch
Incidence	Twice per maneuver
Estimated Time (Sec)	106-172

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	<u>1- Unlock and open hatch (1)</u>
Equipment	Latch Handle and Indicators
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Latch open/closed indicator, airlock press indicator
Diagnosis and Decisions	Latch in closed position, door closed and seal, move handle 1/8 turn counter clockwise to unlatch door. Check airlock to see if pressure balances.
Action	Unlatch door
Feedback	End of stop causes motion cessation of latch then pull door full open
Incidence	Twice per maneuver
Estimated Time (Sec)	3-5

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	<u>2- Inspect Seal Area and Airlocks Internals</u>
Equipment	Communications Gear
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Visual recognition
Diagnosis and Decisions	Recognize airlock and seal area in visual working order preliminary to passageway entry.
Action	Manually check for seal and seal surface continuity. Oral communication.
Feedback	Visual and manual continuity
Incidence	Twice per maneuver
Estimated Time (Sec)	15-20

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	<u>3-Enter Airlock</u>
Equipment	Communications gear
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Suit pressure gauge and air supply gauge
Diagnosis and Decisions	Check suit pressure, continuity, airlock interior, preparatory to turn around for door latching.
Action	Inspection airlock interior and suit gauges, oral communication free float entry
Feedback	Visual continuity and accepted values, feel of suit
Incidence	Once per maneuver
Estimated Time(Sec)	8-10

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	4- Turnaround
Equipment	Communication gear
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Suit pressure and air supply gauge
Diagnosis and Decisions	All lines and appurtenances clear, pressure O.K., clear to turn around
Action	Fold knees in close, rotate body turn 180° in airlock
Feedback	Proximity and impact with airlock interior
Incidence	Twice per maneuver
Estimated Time (Sec)	15-20

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	<u>5-Close hatch and lock</u>
Equipment	Communication gear, latch handles and indicators
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Visual aspect of communication lines
Diagnosis and Decisions	Communication lines clear, no hang-up of personal equipment or appurtenance pressure suit check normal, latch in open condition, rotate door. Seal-mating check, then handle turn 1/8.
Action	Rotate door manually, check seal engagement rotate latch 1/8 turn. Inspect.
Feedback	Visual continuity, latch unlock door inertia, door reaches end of travel, seal compression, latch drag and final mating.
Incidence	Twice per maneuver
Estimated Time (Sec)	5-10

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtask	6-Turnaround
Equipment	(DUPLICATE OF 4 PREVIOUS)
Support Equipment and Personnel	"
Displays	"
Diagnosis and Decisions	"
Action	"
Feedback	"
Incidence	"
Estimated Time (Sec)	15-20

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	6A-DEPRESSURIZE AIRLOCK PREPARATORY TO EXIT TO SPACE (Task not defined at present for the initial feasibility experiment
Gross Tasks/ Subtasks	7-Approach, Unlock and Open Hatch(II)
Equipment	(DUPLICATE OF 1) Latch handles and indicators
Support Equipment and Personnel	"
Displays	"
Diagnosis and Decisions	"
Action	"
Feedback	"
Incidence	"
Estimated Time (Sec)	5-7
Comments	Greater time required than in (1) due to different aspect/attitude

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	8-Exit Airlock
Equipment	Communication gear
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Visual aspect of communication lines and exit area. Safety hook-up, suit pressure. Indicators-radiation temp. of exterior etc.
Diagnosis and Decisions	Recognize seal area and exit are operational check continuity
Action	Inspection safety line hook-up, arrested exit and motion stabilization, communication with interior.
Feedback	Visual continuity, impact with airlock, slack take up and impact of arresting gear.
Incidence	Once per maneuver
Estimated Time (Sec)	30-60

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	<u>9-Turnaround</u>
Equipment	Communication Gear
Support Equipment and Personnel	Communication gear, test director, balast wt. disconnects, constant pressure relief valve
Displays	Visual aspect of communications lines, exit area safety hook-up, suit pressure indicators-radiation, temp. of exterior etc.
Diagnosis and Decisions	If safety hook-up and suit appurtenances clear, proceed with turn around
Action	Rotation of body to airlock, stabilization of motion
Feedback	Visual motion cues, continuity and impact and restraint due to arrest gear.
Incidence	Once per maneuver
Estimated Time (Sec)	5-10

AIRLOCK INGRESS/EGRESS MANEUVER (NORMAL MODE)

Gross Tasks/ Subtasks	10-Approach, close hatch, for possible exit of safety man
Equipment	(SAME AS 5 PREVIOUS)
Support Equipment and Personnel	"
Displays	"
Diagnosis and Decisions	"
Action	"
Feedback	"
Incidence	"
Estimated Time (Sec)	5-10

TABLE II Ingress/Egress Task Analysis-Reduced Version-Experiment

Maneuver- Normal, Airlock Entry/Exit

Maneuver Subtasks-

A- Approach hatch, Unlatch hatch (I), Open hatch (I)

B- Airlock Entry

C- Turnaround, Close hatch (I), Lock hatch (I)

D- Execute turnaround, Approach hatch (II)

E- Unlatch hatch (II), Open hatch (II)

F- Airlock Exit

G- Turnaround (external), Close Hatch (II), Lock Hatch (II)

TABLE III

AVERAGE '0-g' TIME FOR EXISTING AIRCRAFT

Aircraft	Initial Airspeed (knots)	h max-h min. (feet)	Initial Angle (deg.)	'0-g'Time (sec)
C-131B	250	2,000	35	15
T-33A	350	5,000	55	30
F-94C	425	8,000	65	40
KC-135	500	10,000	50	35
F-100F	685	20,000	75	60
F-104A	800	30,000	$75\frac{1}{2}$	80
X-15	4500	500,000	--	300

TABLE IV Test Schedule for Zero Gravity Aircraft Flight

Direction: Circular to Oblong, Unpressurized/Suited

Maneuver No.			Estimated Time
1	1.	Approach and Unlatch Door	5 sec.
2	2.	Enter Airlock	8 sec.
3	3.	Turn Around and Latch Door	5 sec.
4	4.	Turn Around and Unlatch Door	5 sec.
5	5.	Exit Airlock	8 sec.
6	6.	Turn Around and Latch Door	5 sec.

Direction: Circular to Oblong, Pressurized (a) 0.5 PSIG

Maneuver No.			Estimated Time
7	1.	Approach and Unlatch Door	5 sec.
8	2.	Enter Airlock	>8 sec. <20 sec.
9	3.	Turn Around and Latch Door	>8sec. <20 sec.
10	4.	Turn Around and Unlatch Door	>8sec. <20 sec.
11	5.	Exit Airlock	>8sec. <20 sec.
12	6.	Turn Around and Latch Door	5 sec.

APPENDIX - I DESCRIPTION OF STUDY AND EXPERIMENTS--PHASE II

Using the data derived in Phase I as a planning and control basis, the experiments and study accomplished in Phase II will concentrate upon the engineering and design--information aspects of ''general'' space station ingress/egress, airlocks and passageways. The main portion of the Phase II experiments will be conducted employing the water immersion/neutral buoyancy mode and will be performed at the ERA facility. Control and validation experiments will be conducted as noted in both the ground/normal and aircraft/balanced gravity modes. These validation experiments will be confined to a single pressure level except for an initial set of aircraft experiments to be performed at the various pressures in order to acquire comparison functional data relative to the balanced gravity mode.

The following factors will be experimentally investigated in Phase II:

- Normal Ingress/Egress Functional Comparison--ground, water immersion--4 pressure levels.

- Emergency Ingress/Egress Performance--ground, water immersion--operating pressure

- Hatch Dimension Variation--water immersion--operating pressure--4 hatches

- Effect of Latch Torque--ground, water immersion, aircraft pressure--4 set levels of torque

- Equipment Operation and Placement--water immersion--operating pressure--various configurations

- Replenishment and Resupply--water immersion, aircraft--operating pressure--6configurations

- Airlock and Passageway Constraints--water immersion--operating pressure--handholds, tethers, fixed--bar

- Normal Operation (a) 5 PSIG--ground, water immersion--single run

The experiments will be performed with the Phase I airlock mock-up utilizing the Navy, Mark IV, Mod I, Arrowhead FPS as modified in Phase I. This modification includes the self-contained breathing unit, weight belts, flexible athletic shoes and pressurization and calibration system developed in Phase I. The following equipment will be employed in Phase II:

- Existing airlock

- Cutouts for hatch dimension variations

- Modified hatches
    - (a) torque measurements handles
    - (b) torque measurements hinges
    - (c) plastic seal flanges

- Mock-ups of equipment to simulate
    - (a) pressurization unit
    - (b) communication units
    - (c) lighting unit

- Handles, rails, eyebolts, clips, etc. to aid in entering, exiting as turnaround

- Mock-up of packages

- Tether reels, tethers, lines

A tentative experiment performance schedule is detailed in Figure 29. It is noted that this schedule is subject to certain unavoidable delays in response to aircraft scheduling requirements at WADC, particulary as regards weather in the period commencing in late October. It is anticipated that the total, aircraft/balanced gravity mode experiments will comprise approximately 40-60 parabolas in the existing WADC, C-131B aircraft.

The study portion of Phase II will concentrate mainly on the planning, instrumentation, acquisition, collation and interpretation of the data from the above experiments and the production of the required interim and final reports. Additional study will be performed relative to experiment modeling techniques necessary for the validation of the water immersion simulation of manned 'Zero-gravity' kinematic and dynamic phenomena.

APPENDIX II- RECOMMENDATIONS FOR ADDITIONAL STUDY AND EXPERIMENTS

During the course of the Phase I experiments, several additonal tasks have been conceived which could serve to amplify and extend the anticipated in Phase II. The major addition would comprise the determination of suited performance in an airlock mock-up wherein the major dimensions and geometry could be adjusted so as to yield a dimensional replication of the experiment data. A preliminary design concept has been derived in which a cylindrical geometry airlock could be made adjustable in length, diameter and door placement over a statistically significant range, i.e. variation of diameter between 4 feet and 7 feet. The variation in geometry would comprise the performance of normal I/E tasks in the 7 foot spherical airlock mock-up currently existing at LRC.

Further, additional effort appears to be warranted relative to the effect on performance of the exact configuration extra-vehicular suits and life support components contemplated for future NASA mission support. These would include the Mercury one-gas suit, the Gemini suit, ''mock-up'' chest and back-pack life support components and ''mock-up'' umbilical life support components.

Operationally, it appears useful to examine and simulate one and two-man rescue and recovery procedures in and through airlocks. This is particularly applicable in combination with the adjustable airlock mock-up previous discussed, in order to determine minimum volume and dimensional restrictions.

During the establishment of the neutral buoyancy weightings in the water immersion mode it became obvious that experiment performance at various subgravity levels such as lunar etc. could readily be achieved. This procedure would provide a means for determining equivalent low-velocity motion performance at various reduced gravity levels and appears applicable to rotating space station and lunar operational design concepts.

The following list summarizes ERA recommendations for additional study and experiment effort on NAS1-4059:

- Variable dimensions, geometry airlock experiments.
- Investigation of the performance and mobility characteristics of the Mercury, Gemini and Apollo EVS during ingress/egress operations.
- Experiments relative to the effects various levels of sub-gravity on ingress/egress.
- Ingress/egress operational constraints dictated by the employment of various self-contained life support components.
- The investigation of multi-manned operations and rescue procedures in airlocks and passageways.